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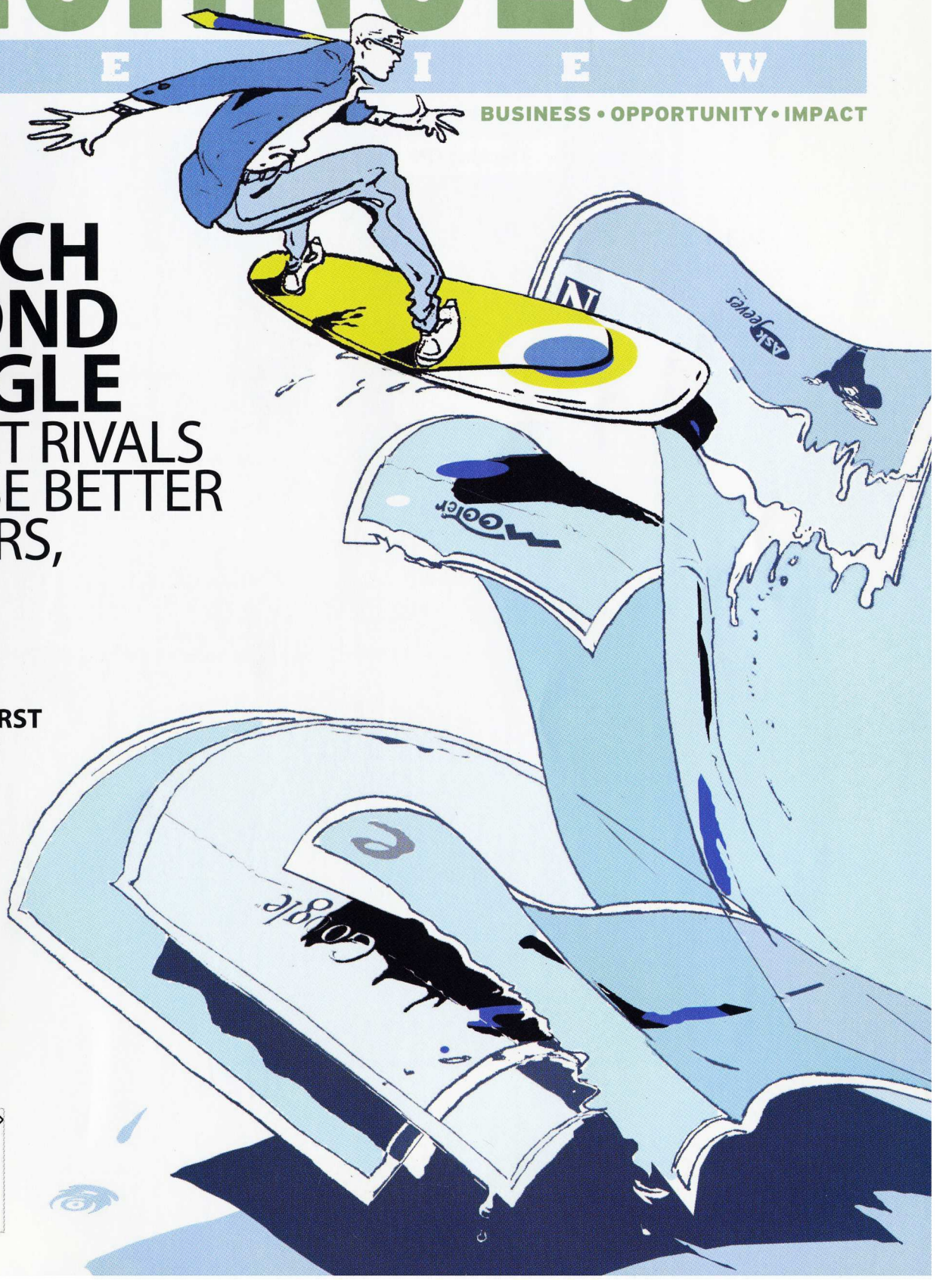

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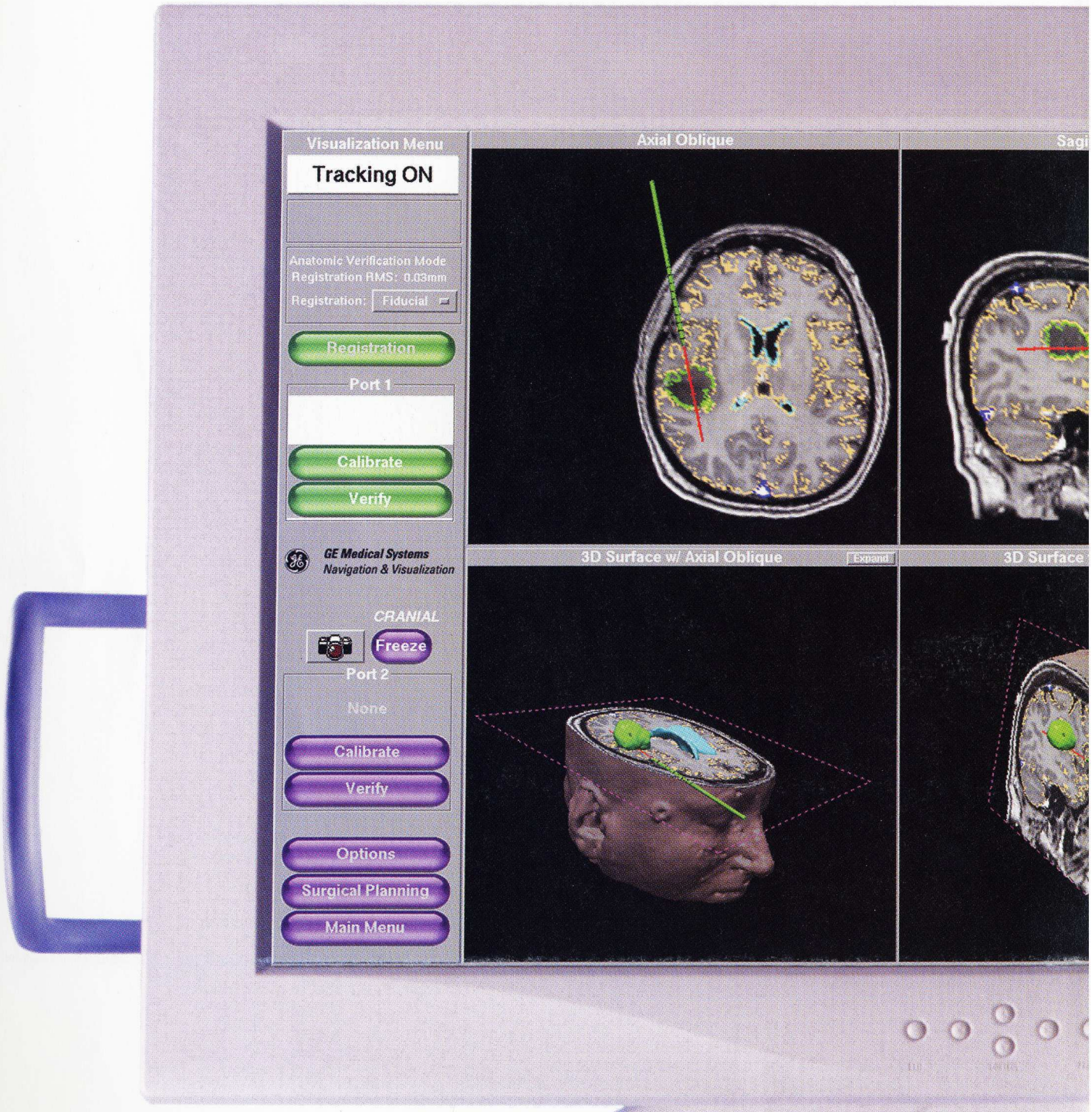
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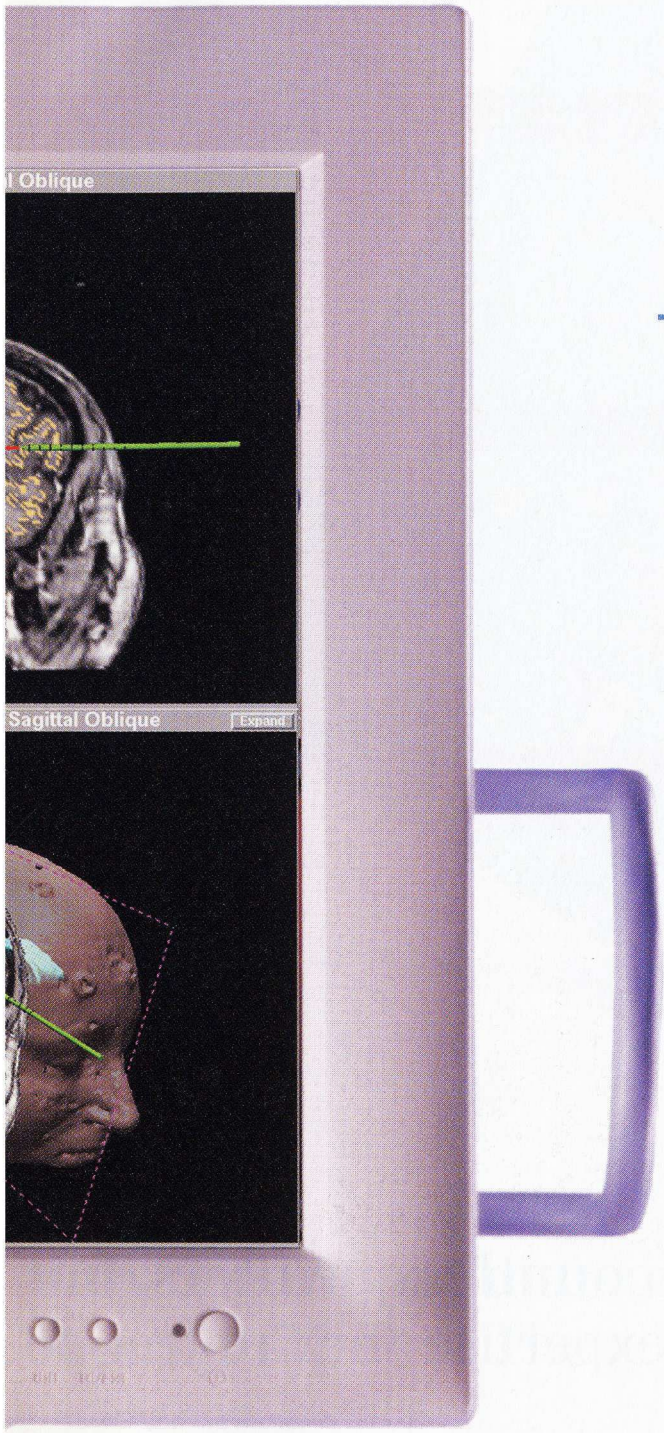

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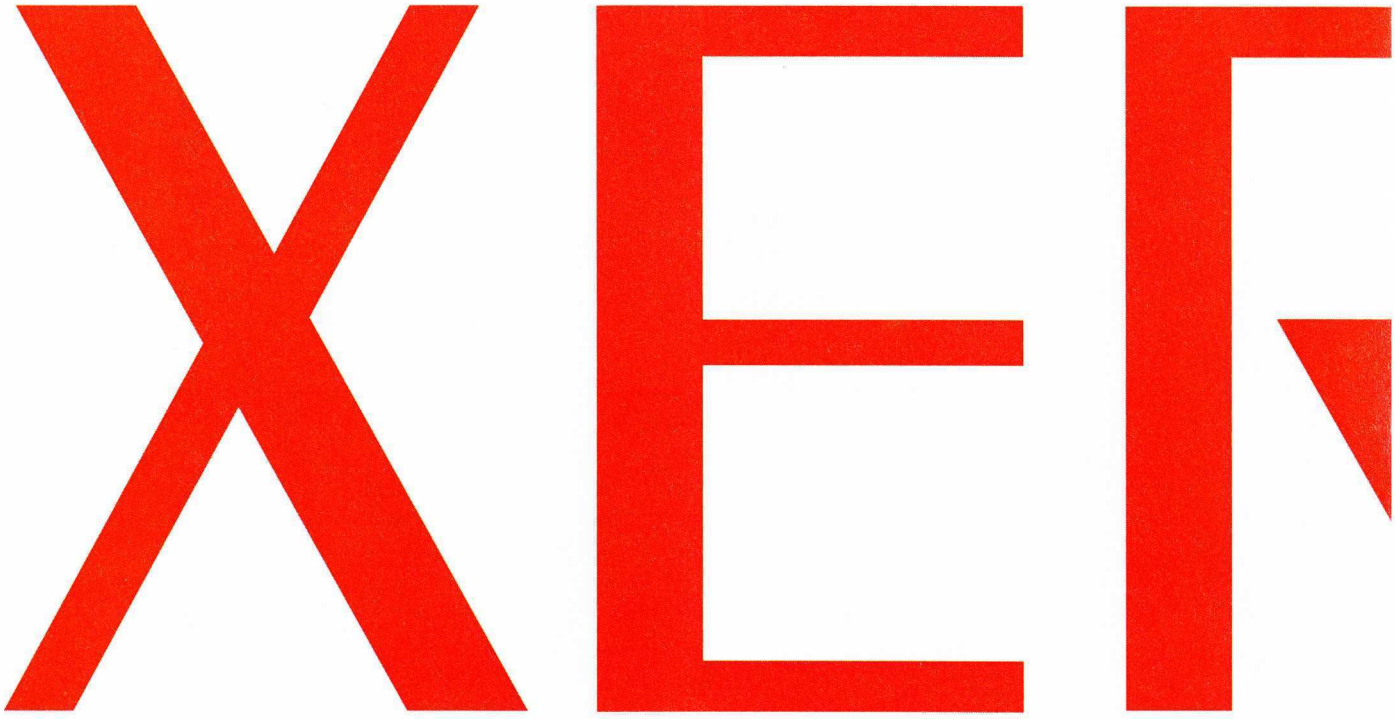

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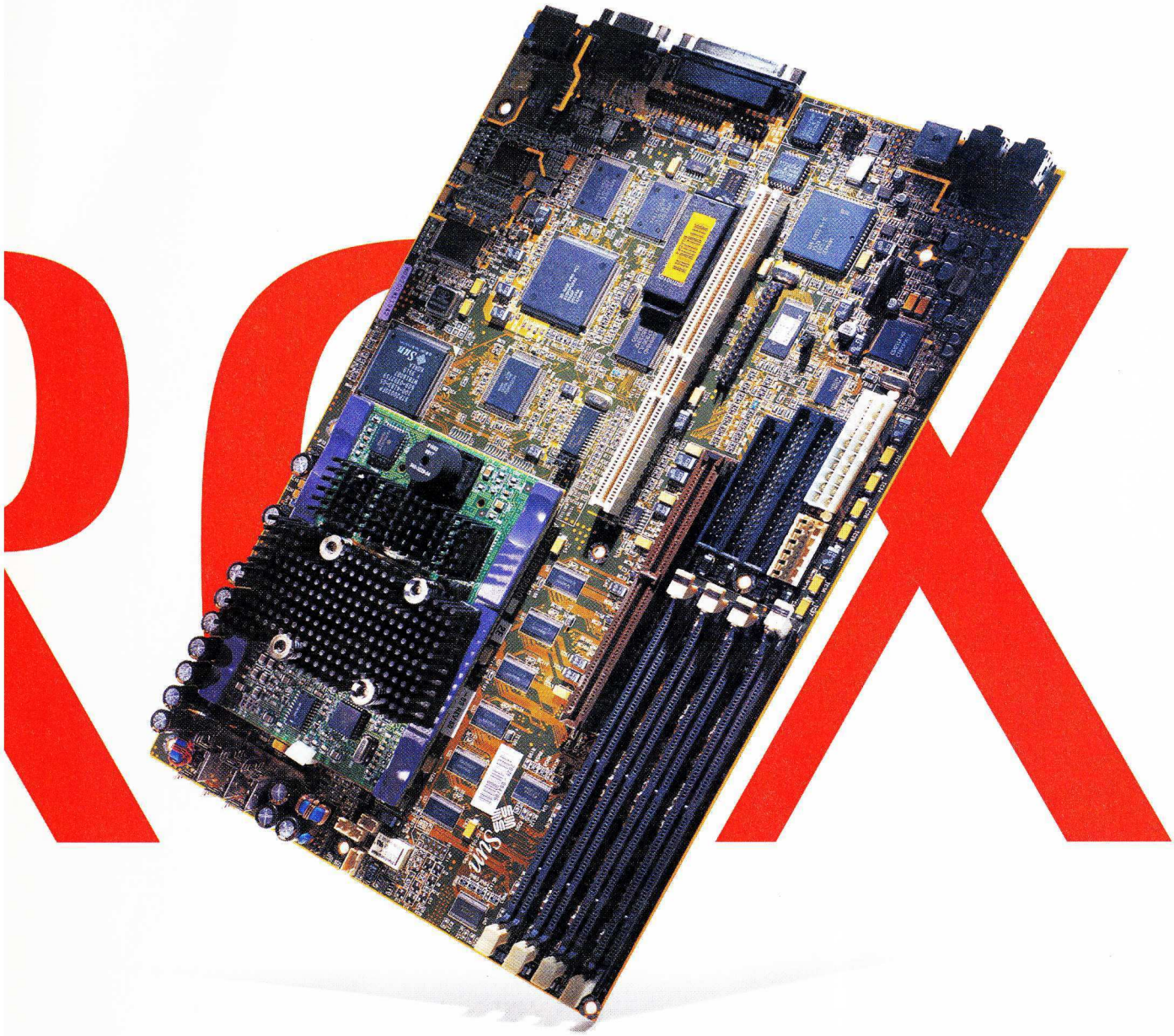

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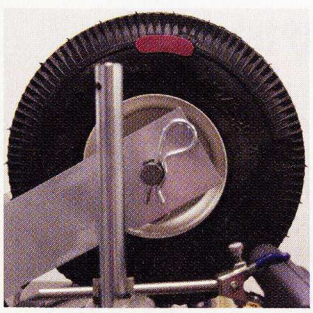
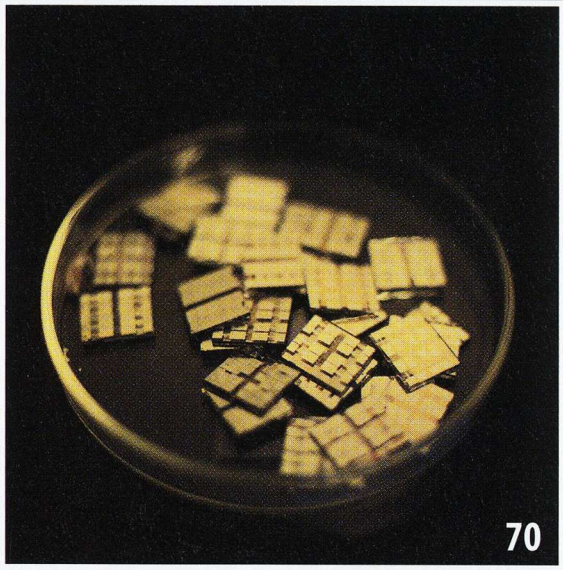


Technology Review
Volume 107, Number 2
March 2004

"We hope the next breakthrough comes from Google—but who knows?"—*Craig Silverstein, p. 36*



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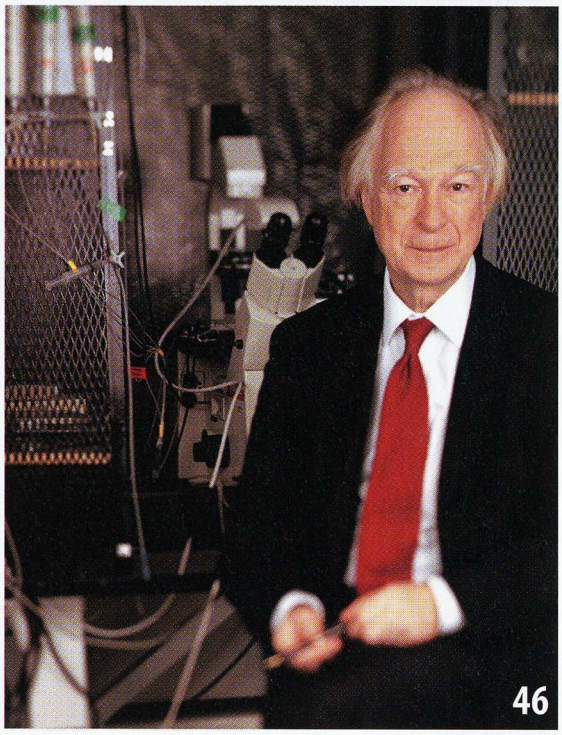

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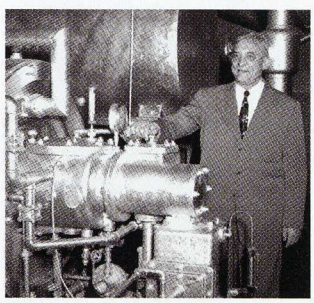

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Sometimes threats don't look like threats. They look like your mobile workers, your sales department or your CFO's daughter. Even the innocent act of downloading a file—one that looks like any other, but is in fact corrupt—can create a costly security breach that can take your business off-line. So how do you defend against threats that take the shape of productive employees? A network with integrated security can detect and contain potential threats before they become actual ones. Whether they're worms, hackers or even well-meaning humans. Security that's about prevention. Not reaction. Visit cisco.com/securitynow to learn more. **SELF-DEFENDING NETWORKS PROTECT AGAINST HUMAN NATURE.**

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The Patriot Act: A Visitor's Tale

THIS IS THE STORY OF...WELL, I CAN'T TELL YOU his name, because, as he told me with a nervous laugh, "I'm still a scared man inside, Bob." ■ Call him Ahmed. He is a citizen of Britain, where he completed his medical residency, but he was born in Pakistan. For the past several years, he has been a faculty member at a leading U.S. university medical center. His wife and children, also British citizens, live here with him.

With all the ingredients of an American success story in hand, why is Ahmed scared? The answer won't surprise you: the USA Patriot Act and other regulations put into effect since Sept. 11, 2001. Few doubt that in the age of terror, greater efforts to monitor foreign visitors to the United States are warranted. However, many leaders worry that federal controls are proving so onerous that they will drive away the foreign talent vital to national competitiveness *(see "Biotech's Big Chill," TR July/August 2003)*. I learned of Ahmed's case at a recent party and thought his story might provide a good reality check on how well we are doing at maintaining this balance.

Ahmed arrived in the United States on a prestigious medical fellowship a few months before September 11. As a British citizen he wasn't particularly worried about how the attacks would affect his family. But he quickly learned that from the U.S. perspective, there are the British, and then there are the *other* British.

The following summer, Ahmed's wife and children vacationed in Britain. During the trip, their U.S. visas expired. Ahmed says it should have taken about 10 days to renew the visas at the American embassy in London. But his wife was told that new visas would not be issued unless Ahmed returned to Britain.

When Ahmed arrived in London, American embassy officials told him everything was in order but that his family's visas would take another five weeks. "So I ended up stranded in London for five weeks, just for nothing," he recalls.

"It's good to scrutinize people. But if they abide by the laws and their records are clean, let them carry on with their lives."

Not long after the family made it back to the United States, all men within the country's borders who were over the age of 16 and nationals—or in some cases just natives—of countries considered to pose an elevated national-security risk were ordered to register with the federal government under a special-registration program. "Being born in Pakistan, even though a British national, I was asked to go through this special-registration program," Ahmed says.

Ahmed spent an entire day at an Immigration and Naturalization Service office being fingerprinted, photographed, and interviewed. Now, although he is free to travel the United States, if he wants to leave the country, he must report to airport immigration authorities before departure for questioning about his itinerary, fingerprinting, and photographing. When he returns, he'll be questioned, fingerprinted, and photographed again. Things like that scare him. Though he wants to visit Pakistan and see his parents more often, Ahmed says, "I've been holding myself back." He has heard about others like him whose reentry to the United States was delayed by months, or denied outright. If and when Ahmed gets a green card, such restrictions should be lifted—but he's nervous about that, too. "It remains to be seen whether I get a green card or not."

Despite his experiences, Ahmed has no problem with the U.S. government monitoring newcomers. "I don't think these rules by themselves are a bad thing," he says. "It's good to scrutinize people. But once they have scrutinized people who are cooperative, who abide by all the laws, whose records are clean, they should let them carry on with their lives. I'm being dealt with as if I'm a terrorist or a criminal, when I should concentrate on what I'm doing here."

Ahmed agrees with those who think the United States is needlessly alienating people who want to come to this country to learn and to contribute. He knows several talented Pakistanis who dropped the idea of working here, and a Turkish colleague was recently told to leave the country without explanation, even though he had been in the U.S. for six years and is a leader in his field.

For a wider perspective, I talked to Ahmed's supervisor. "It's pretty wild," he says. "Huge amounts of paperwork and delays. I've been through it with a couple of guys." It's usually the cream of the foreign crop who are accepted into U.S. fellowship programs, he says, so it's particularly difficult to see such talent get such a hard time.

Like Ahmed, I support increased monitoring of certain foreign nationals. I'm not even particularly troubled that we seem to have overdone it on the first pass: that's a natural reaction for a nation that lost thousands of citizens, friends, and relatives in a single morning. But it's time to refine the program and make it both smarter and more fair. We owe it to our guests, and to ourselves, to do better. **Robert Buderi**

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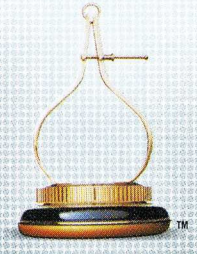

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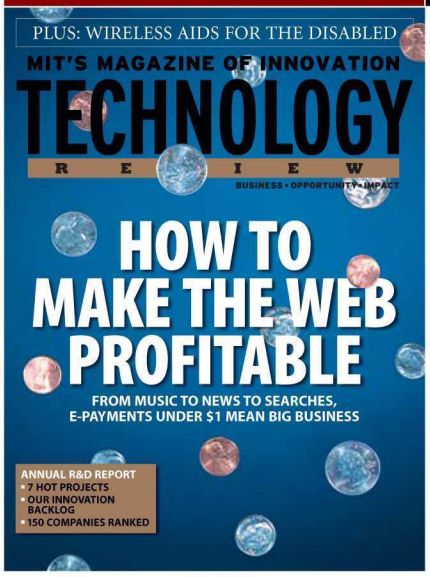

"Micropayments are a neat technology, but they are likely to play only a minor role in the economy."

BIG QUESTIONS ABOUT SMALL PAYMENTS

"THE WEB'S NEW CURRENCY" (*TR* December 2003/January 2004) presents nicely the case for micropayments. However, contrary to the article's implication, skepticism about micropayments is based not on general qualms about the spread of a new technology but rather on economics, psychology, and marketing.

Even if the perfect micropayment scheme were invented—cost nothing to operate, was perfectly secure, and required no special effort by consumers—I predict that it would not become widely used. Standard economic models show that sellers can derive more revenue from selling bundles, as in the Microsoft Office suite, than from selling individual pieces. Behavioral-economics factors show that customers' usage drops dramatically when there is even a tiny payment, and that consumers are willing to pay more for simple pricing plans, especially flat rates. Micropayments are a neat technology, but they are likely to play only a minor role in the economy.

Andrew Odlyzko
University of Minnesota
Minneapolis, MN

THE BUSINESS MODEL FOR THE MICROpayment companies outlined in your article is not to replace or compete with an existing payment mechanism; rather, it allows valued content to be monetized and distributed. While none of us would pay 50 cents for a newspaper article from today's paper over the Web, we may choose to pay for archived content that is on a subject of interest—especially if retrieving the content was otherwise difficult, time-consuming, or prohibitively expensive. Right now you must submit personal information and subscribe for a period of time instead of pay as you go. The fee (a percentage of the transaction amount) is irrelevant because the transaction amount is small, and the cost of providing the content is incremental.

Joseph C. Niederberger
Pleasant Hill, CA

WHAT IF I JUST WANT ONE ARTICLE FROM a newspaper, and then six months later, one song download? I don't know about you, but I'm not too excited about the need to wait until I have completed 100 or more transactions before I get charged on my credit card.

Raymond Collins
Miami, FL

IF MICROPAYMENT COMPANIES EVER became large enough, established credit card companies would surely take notice. These companies could very easily introduce a competing micropayment scheme of their own just by slapping a new interface on their existing systems and cutting their prices. Once these giants enter the market, they'll have an overwhelming advantage because they already have the critical mass that right now is Peppercoin et al's biggest obstacle to success. Nevertheless, consumers and online merchants will benefit. Peppercoin's competition will drive down the market price of online payments and make micropayments viable—even if the way we're paying for them is through a credit card company.

Paul L. Mirer
Rockville, MD

SPONTANEOUS COLLABORATION?

THERE'S ONE PROBLEM WITH MICHAEL Schrage's interesting idea that biotech innovation can be fueled by veterinary medicine ("Medicine Goes to the Dogs," *TR* December 2003/January 2004): veterinarians, doctors, and scientists will not spontaneously collaborate. An organization should be established that provides a medium for interactions between veterinary and medical researchers.

Mark McCollum
Miami, FL

INNOVATION BACKLOG

IN RESPONSE TO KENAN SAHIN'S article ("Our Innovation Backlog," *TR* December 2003/January 2004), it's not so hard to understand the reluctance to invest in technology. Many people invested heavily in "Internet" without understanding what they actually were putting their money into; they did so because the Net had "flash" and "now" to it. Many of those dollars were absorbed in huge salaries paid to executives who had no clue as to where the value in their product lay, only that they were developing something cool. It is up to the innovator to make a clear path to value, and the investor to demand that path. Any investor who fails to do this has failed to do his job and has no one else to blame but himself if he loses money.

John Peters
Fremont, MI

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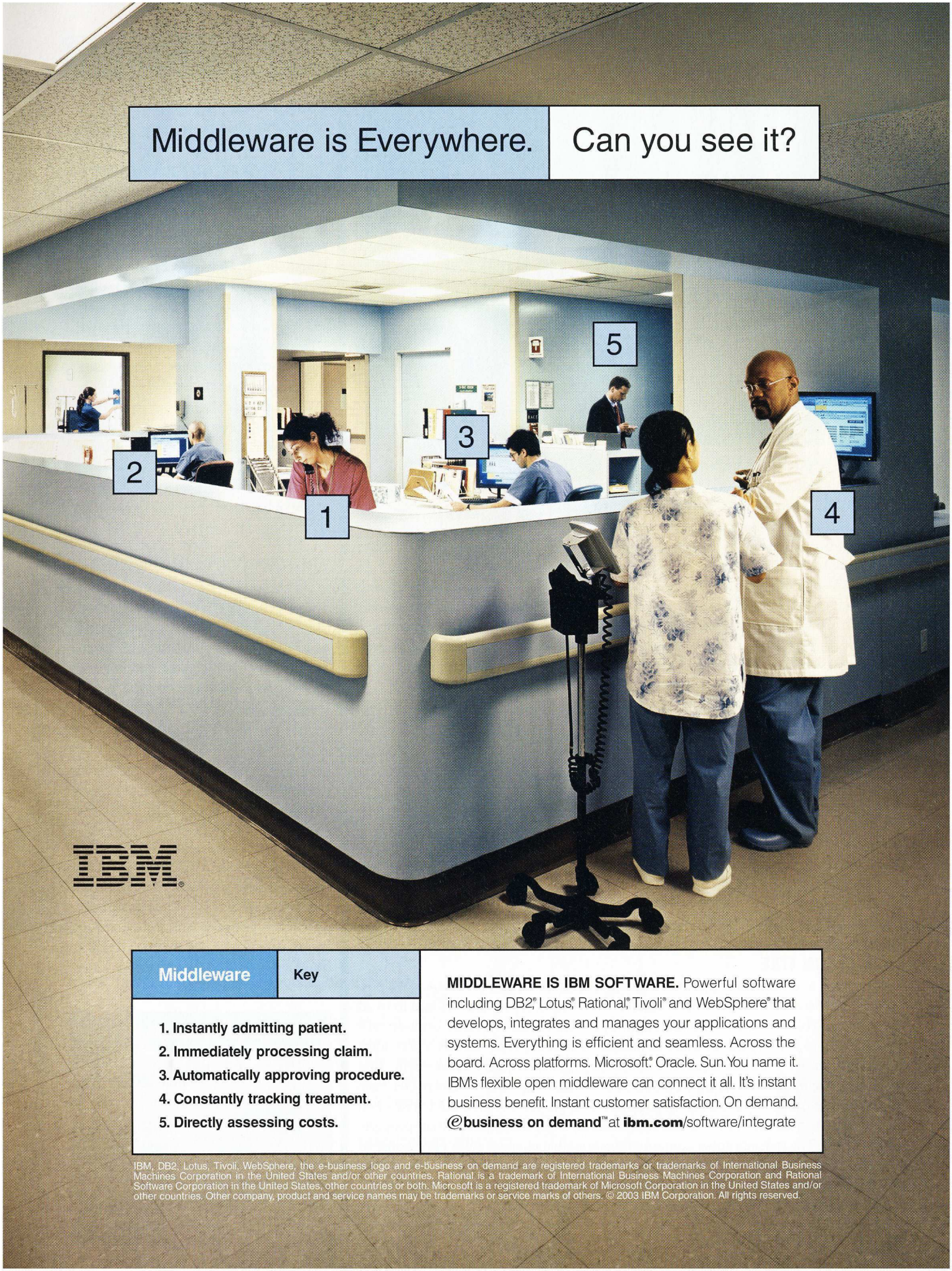

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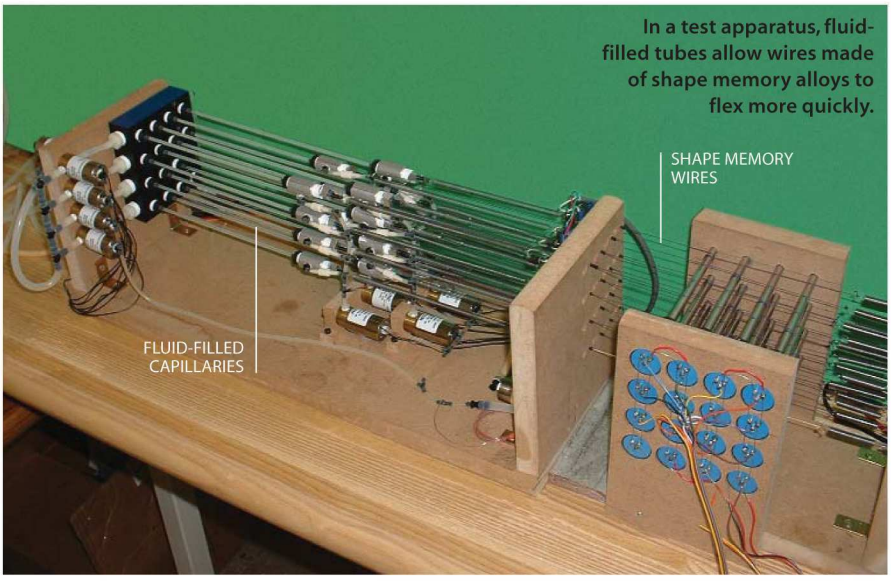

In a test apparatus, fluid-filled tubes allow wires made of shape memory alloys to flex more quickly.

MOVERS AND SHAKERS

ROBOT MAKERS HAVE LONG SOUGHT TO REPLACE THE PUNY ELECTRIC MOTORS and heavy hydraulic actuators that drive most of their machines with something more musclelike. One possibility is shape memory alloys, metals that contract when an electric current heats them to a certain temperature and return to their original shape as they cool. But such alloys switch shapes slowly, making them hard to use as artificial muscles. Mechanical engineers Stephen Mascaro of North Dakota State University and Harry Asada of MIT have a potential solution: fluid-filled tubes containing wires made of a shape memory alloy. The fluid speeds the alloy's cooling, so it changes shape in only .15 seconds—more than an order of magnitude faster than previous systems. Asada hopes to use the networks to replace the electric motors used for seat and mirror adjustments in cars, but eventually the technology could bulk up robots with lifelike muscles.

A special strip of rubber turns red when a tire gets too hot.

CHAMELEON TIRE

MORE THAN A QUARTER OF ALL PASSENGER VEHICLES ON THE ROAD IN THE United States have one or more underinflated tires—a condition that can lead to tread separation and blowouts. The National Highway Traffic and Safety Administration estimates that up to 10,000 injuries could be prevented annually if all vehicles had systems that warned drivers of underinflation. Frank Kelley of the University of Akron in Ohio and Barry Rosenbaum of Omnova Solutions, a chemical company in Fairlawn, OH, have devised a simple solution: a rubber material that changes color from black to red when tire temperatures rise above 77 °C (underinflated tires get much hotter than properly inflated tires). The special rubber contains a material that changes color in response to temperature; a strip of the rubber could be built into the sidewalls of tires, visible as a red ring when things get too hot. The researchers have formed a company called TCS Polymers and hope to sell the rubber to the tire industry in three to five years.

E-MAIL INSPECTOR

Spam filters weed out incoming junk e-mail, but a growing number of companies need to worry about outgoing messages, too. That's because strict new regulations on financial disclosures and the privacy of health data carry heavy fines if breached—whether intentionally or accidentally. Proofpoint, of Cupertino, CA, is working on software that automatically identifies and intercepts sensitive outgoing e-mail. The software's artificial-intelligence algorithms can learn to distinguish between documents that have many similarities but should be classified differently—for example, between a routine e-mail from one doctor to another and a similar but unauthorized message that reveals a patient's private medical information. The company expects to incorporate the algorithms into its spam detection software by the middle of this year.

BRIDGE OVER RISING WATER

IN 2002, SEVERE FLOODING IN CENTRAL Europe left millions isolated. Soon, however, a floating aluminum bridge could help keep flood-prone communities connected. The modular one-lane highway can be assembled in just three days. A 70-meter prototype was built on a lake in the Netherlands; 18 factory-built sections were slotted together on site. Polystyrene foam inside each section makes the road unsinkable, and foam-filled outriggers increase stability. Cars can cross the road at speeds of up to 80 kilometers per hour. Rural Dutch communities are considering a longer-term deployment of the road, which was developed by a consortium of Dutch companies. There's also interest from Norway and eastern Europe, where it can take up to three years to build a conventional road across waterlogged land.

A floating road could keep flooded communities connected.

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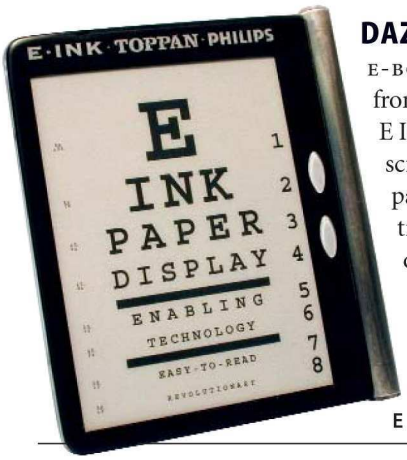


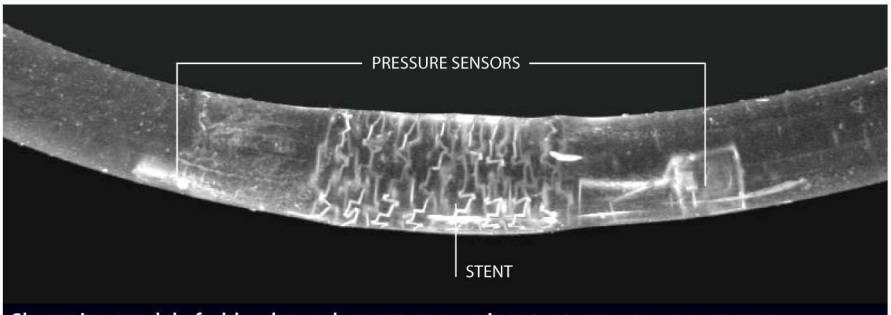
DAZZLING DISPLAY

E-BOOK READERS—HANDHELDS THAT DISPLAY THE CONTENTS OF BOOK FILES DOWNLOADED from the Internet—just got a whole lot more readable. Philips Electronics and Cambridge, MA-based E Ink have developed a prototype electronic display that looks like paper and ink, not a dim, fuzzy screen. The device uses E Ink's tiny fluid-filled balls containing oppositely charged black and white particles, which are layered in a thin film on a sheet of plastic or glass. Connecting this film to electronics allows the reader to display text and graphics by controlling the voltage across each ball, determining whether it appears black or white. The result: higher contrast than newspapers and better resolution than laptop screens. The 15-centimeter-diagonal display is about half the weight and thickness of comparable liquid-crystal readers. It has been in the works for a few years, but this is the first version that is ready for commercial production. Look for the new readers to hit shelves later this year.

E Ink's display could make e-books look more like the printed page.

RADIO STENT

INSIDE THE CORONARY ARTERIES OF MILLIONS OF AMERICANS ARE STENTS, metal mesh tubes the length of a dime that prop open narrowed blood vessels to help prevent heart attacks. But in about a quarter of patients, scar tissue builds up in and around the stents three to six months after they're inserted, threatening to reclog arteries. Electrical engineer Yogesh Gianchandani and his team at the University of Michigan have designed a stent that can monitor blood pressure as an early warning sign of renarrowing. The researchers attached a tiny, flat pressure sensor to the stent and modified the pattern of the wire mesh so that it acts as an antenna. The stent wirelessly transmits pressure and flow information through the skin to an external device held against the chest. Gianchandani says the device could allow patients to monitor their blood pressure at home, saving repeated trips to the cardiologist and avoiding invasive procedures to check for arterial reclogging. The researchers have tested their prototype in simulated arteries and are now fine-tuning the device. They plan to have completed animal tests in about two years and hope to have the "stentenna" on the market in three to five years.



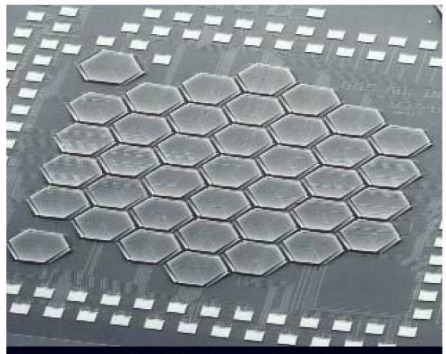
Shown in a model of a blood vessel, an artery-opening stent can act as an antenna, transmitting data from tiny blood pressure sensors that warn of vessel narrowing.

CALCULATING DRUG DESIGN

The pharmaceutical industry dreams of using computers to predict which potential drugs will work best and have the fewest side effects. Until recently, the software that performs such simulations has been slow, difficult for the average chemist to access and use, and worst of all, often inaccurate; but a collaboration between University of North Carolina at Chapel Hill computational chemist Alex Tropsha and IBM is making predictive drug screening easier and more accessible. Researchers who have encountered difficulty with a drug candidate can submit data on its structure and biological functionality to Tropsha's program via a Linux-based Web portal designed by IBM. Running on a cluster of high-powered computers, Tropsha's software screens a large database of compounds to help identify more-promising candidates. "Now, all a chemist who uses the program has to know is chemistry," says Tropsha. The program has already singled out compounds that could help treat conditions such as convulsions and hemophilia, and Tropsha hopes to commercialize the software this year.

EYE GAZING

EYE DOCTORS COULD SOON GET A BETTER LOOK AT YOUR RETINA THANKS TO a technique used by astronomers to peer into the far corners of the galaxy. Using principles similar to those behind the Hubble Space Telescope, researchers from the University of California, Berkeley, and the University of Rochester have built a device that hooks up to standard eye-imaging equipment and improves resolution by a factor of three to five. That could allow doctors to image blood cells and photoreceptors in the eye—not possible in today's exam rooms—and detect diseases like glaucoma at an earlier stage. The device uses a six-millimeter-wide array of tiny movable mirrors to focus incoming light and correct for imperfections in the eye, such as a misshapen cornea. A built-in computer does the optical calculations and instructs the array to deform hundreds of times per second. In 2002, the researchers founded Iris AO in Berkeley, CA, to commercialize the technology. A federally approved device should reach doctors in three to five years.



A close-up of a chip shows tiny mirrors that could help sharpen eye exams.

COURTESY OF IRIS AO (GAZING); COURTESY OF KENICHI TAKAHATA, UNIVERSITY OF MICHIGAN (STENT); COURTESY OF E INK (DISPLAY)

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Disruptive Incrementalism

MY FAVORITE EXAMPLE OF "INCREMENTAL INNOvation" belongs to *Dilbert*—the cartoon, not the character. Even before the Internet was a gleam in Jeff Bezos's eye, Scott Adams—*Dilbert*'s creator—got his syndicate to agree to attach his e-mail address to the strip. ■ The reason, Adams has explained, was to see what kind of reader feedback—if any—e-mail accessibility might generate. In fact, he still gets much of his best *Dilbert* material from reader e-mail. "Yes, they send me ideas," Adams smirked in a *Washington Post* online discussion. "But the lazy %#$*s refuse to draw the comic too, so I have to do that part."

Indeed. But the simple act of tagging a comic strip with an e-mail address proved brilliantly innovative. Getting your fans to subsidize your creativity—for free!—is an enviably efficient business model. What *Dilbert*'s dad did might be called—with apologies to innovation guru Clay Christensen—a "disruptive incremental innovation."

While technically less innovative than the shifts from, say, piston to jet engines or vacuum tubes to transistors, disruptive incremental innovations have profound effects on business. It's not about simply extending a brand; it's about surprisingly cheap, surprisingly easy-to-implement ideas that transform how value is created or perceived. The ideas underlying the successful incremental disruptor almost always seem blindingly obvious in retrospect. Any competitor could have done it.

Apple's iMac offers a case study in disruptive incrementalism. For all intents and purposes, desktop personal computers were little more than bland beige boxes sold on the basis of features, functionality, and price. The PC industry—IBM, Compaq, HP, Dell, Fujitsu, Hitachi, and so on—publicly considered the outward appearance of their machines to be irrelevant to their customers' needs and desires. At least, that's what their research said.

The iMac offered little in the way of new functionality. But customers thought color and styling were innovations and said so.

Apple, with its flair for inspiring industrial design but minuscule market share, decided that looks *could* matter. The resulting iMacs—which offered shockingly little in the way of new features or functionality—represented a triumph in plastic repackaging of an existing product. But they were sold in an intriguing palette of colors—including tangerine(!)—and a Frank Gehry-esque housing that seemed, for want of a better word, *cool*.

While none of Apple's competitors or, for that matter, the technical media considered the iMac particularly "innovative," customers disagreed. They thought color and styling were innovations and said so. The iMac proved a breakout product for Apple and did wonders for both its sales and share price. It also changed marketplace expectations about the visual aesthetics of PCs and other devices.

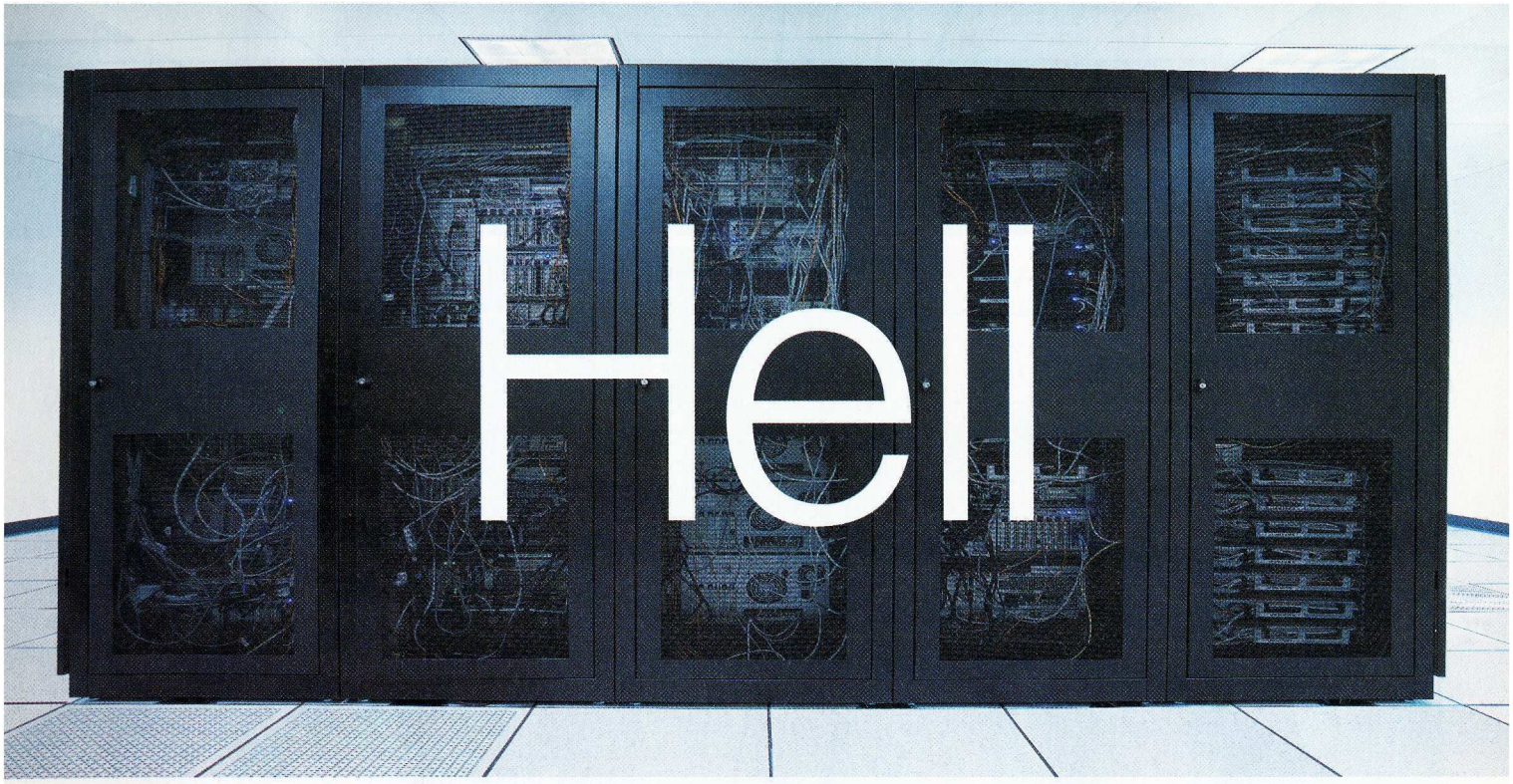
Innovation cynics might say that what Apple's Steve Jobs did was tantamount to GM's Harley Earl slapping fins and chrome grilles on automobiles. But heck! If it sells significantly more cars or more personal computers, then it's significantly innovative.

The same holds true for James Dyson's clever idea in 1993 to make the housings of his novel cyclonic vacuum cleaners transparent. Why? Dyson figured that, far from feeling "icky" about seeing their vacuum cleaners filled with dirt and grime, his customers would love to see how well their machines were working. Part of his rationale was that existing suction vacuum cleaners did an inferior job of cleaning—hence no transparent vacuum cleaner bags (even though they would have been easy to produce). While the costs of transparency were minimal, its perceived customer benefits were immense. Customer research affirmed that being able to see how well the Dyson cleaned was a valuable feature. Transparency profoundly differentiated Dyson from its competition—a classic disruptively incremental innovation.

Behind every disruptive incremental innovation, however, is a *big* idea. For Scott Adams, it was the recognition that readers could be part of his creativity supply chain; for Steve Jobs, that customers might be willing to pay a premium for how a computer looks as well as for how it works; for James Dyson, that letting customers literally see the difference in cleaning quality would make them trust his innovation more and recognize its value.

To be sure, there is a huge difference between radical incremental innovations—innovations that truly are cheap and easy to implement—and radical innovations that *look* cheap and easy to implement. When Procter and Gamble decided in the 1980s to combine shampoo and conditioner in a single product, for example, the job proved much, er, hairier than the company had anticipated; as it turns out, the two substances have very different chemistries. But the opportunities for disruptive incrementalism seem to be increasing for innovators who believe that even small revolutions can have disproportionately big results. TR

Michael Schrage is a researcher and consultant who writes widely about innovation.



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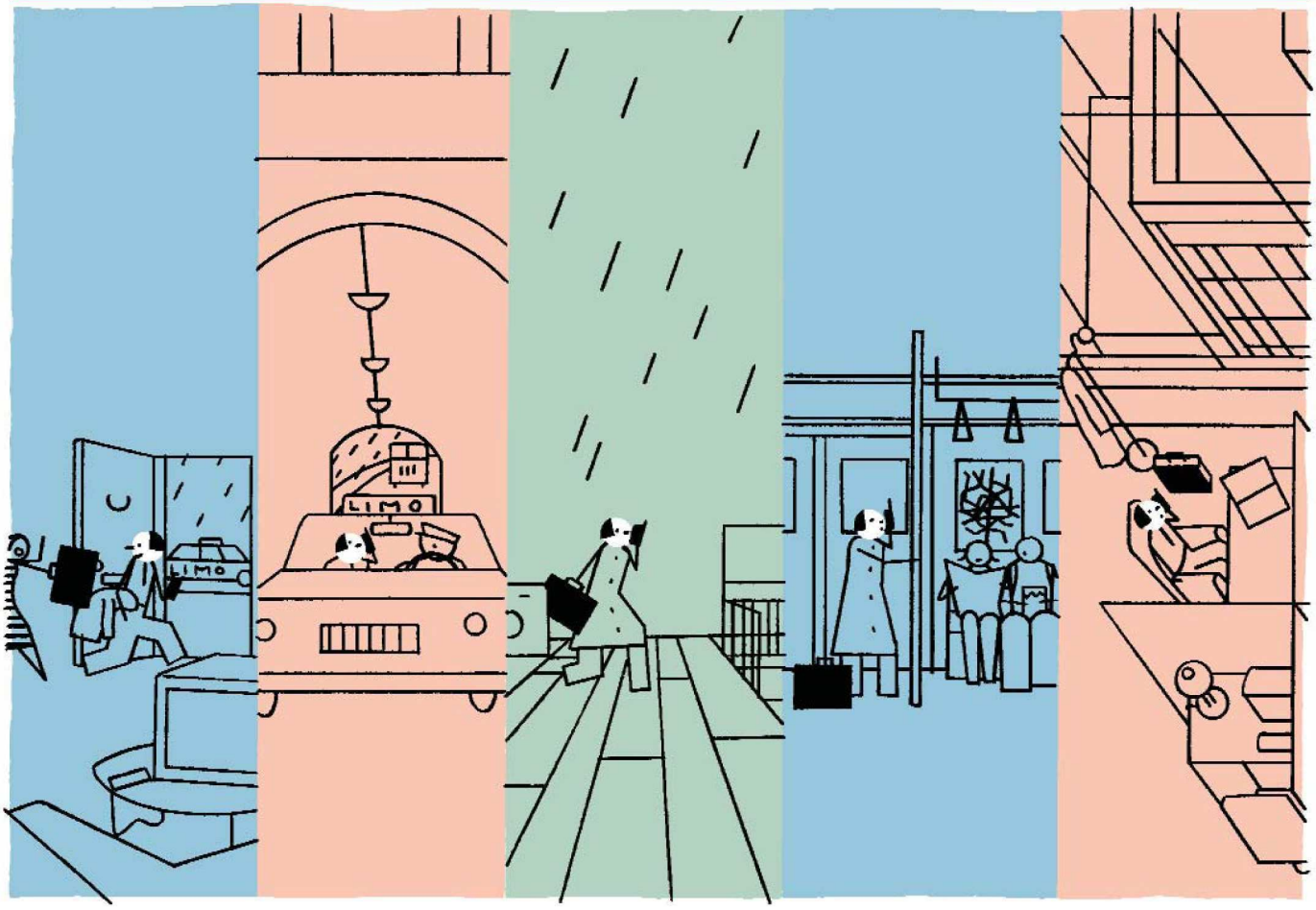


One Person, One Phone

As Wi-Fi networks link with cellular networks, telephonic unity nears. **BY CORIE LOK**

THE USE OF CELL PHONES is likely to expand even further this spring when all U.S. residents gain the ability to transfer landline phone numbers to their mobiles.

But there's a stumbling block in the path of the cell-phone juggernaut: poor reception inside many buildings that makes cellular networks not quite reliable enough to be the main phone systems for offices—or even for residents of many apartment buildings. So despite the rise of cellular service, most people still have traditional business and home phones.

In the next year, though, Wi-Fi—the popular wireless technology installed in many buildings that allows laptop users to surf the Net—will make mobile phone calls work virtually anywhere. An emerging crop of technologies will stitch Wi-Fi networks and existing cellular networks together, allowing calls to automatically switch between the two. The percentage of mobile phones that are Wi-Fi enabled will grow from near 0 percent last year to 85 percent by 2007, predicts On World, a San Diego, CA-based wireless-market research firm. "I'm very optimistic that within 10 years, most people will be carrying a single phone and making and receiving most of their personal and business calls on that one device," says J. Gerry Purdy, an analyst with Mobiletrax, a Cupertino, CA, mobile- and wireless-research firm.

This trend could boost the use of the Internet to carry telephone calls, too. Internet calls have accelerated in recent years, as more people have gained access to faster connections, which improves service quality. Adding Wi-Fi to the mix means users no longer have to be sitting directly in front of their computers when they make calls.

And once cell phones can also understand Wi-Fi signals, callers can

LAURENT CILLUFFO

enjoy the best of both worlds—the cheapness of Internet calls and the flexibility of mobile phones.

Such dual-mode phones are on the horizon; Motorola of Schaumburg, IL, plans to start selling one such phone—cellular one minute, Wi-Fi the next—later this year. Once dual-mode phones and the merger of Wi-Fi and cellular take hold, you can make and receive all your calls on one phone no matter where you are. Forget about dead spots inside your office building: your calls will switch unnoticeably from your office Wi-Fi network to the cell towers lining the highway and finally to your in-home Wi-Fi network.

Future mobile phones will use Wi-Fi at the office and seamlessly switch to cellular on the road.

Indoor Wi-Fi coverage would be offered by cellular carriers as an added service. Subscribers would likely have to pay an extra $5 to $20 a month for it, says Ken Kolderup, vice president of marketing at Kineto Wireless in Milpitas, CA, but they'd get cheap Internet calls when they were on the Wi-Fi network. And by providing more reliable service indoors, the cellular carriers would be able to fully compete with traditional telephone companies.

Realizing this vision will require new hardware. Motorola, for instance, has partnered with Avaya, a Basking Ridge, NJ, voice- and data-networking company, and Proxim, a Sunnyvale, CA, wireless-equipment company, to develop telephone-networking hardware for office settings.

And Kineto has developed a network controller that can be installed on a cellular-telephone company's network to bridge cellular and Wi-Fi. If a cell-phone user is indoors and near a Wi-Fi access point, his or her phone would sense the stronger Wi-Fi signal and tell the controller that it should route any incoming calls through the Internet, and ultimately through the local access point. Three carriers in the United States and Europe are now testing Kineto's technology; Kineto expects dual-mode service to be available this year.

Meanwhile, a related trend is emerging: Wi-Fi communications systems that replace paging systems in workplaces like hospitals. For example, Vocera Communications of Cupertino, CA, installs a server that routes voice data over the workplace's internal computer network, to and from Wi-Fi access points in the ceilings. Workers have conversations via special badges that respond to voice commands. This is quicker and more convenient than pagers, and provides more reliable connections than cell phones.

All told, about 100,000 people in the United States are now making Wi-Fi phone calls at work. And that market is predicted to grow from $16.5 million in 2002 to $500 million by 2007, according to the Scottsdale, AZ, market research firm In-Stat/MDR. "This is only going to expand," predicts Purdy, who says the technology will soon branch out from hospitals and retail settings to business offices.

A badge enables push-button Wi-Fi calls in settings like hospitals.

Of course, a number of significant hurdles remain. Wi-Fi sucks up a lot of power, so the new dual-mode phones will need to be very power efficient or have better batteries. Voice quality over the Internet—despite having improved in recent years—is still rougher than what's available on traditional landlines. And putting too much voice traffic on Wi-Fi networks can slow them down.

Still, with more phone calls going over the Internet, more Wi-Fi networks being installed, and cell carriers looking to spread their coverage indoors, more and more people are likely to cut their telephone cords. TR

COURTESY OF VOCERA COMMUNICATIONS

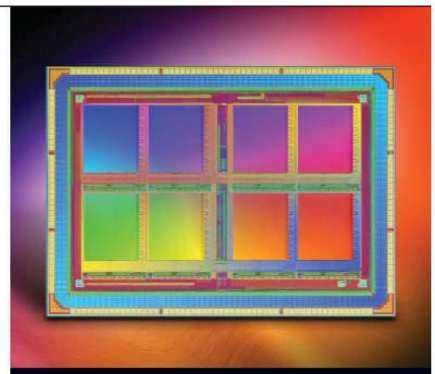
A SAMPLING OF WI-FI TELEPHONE TECHNOLOGY

COMPANY	TECHNOLOGY
Avaya (Basking Ridge, NJ)	Internet-based telephone system switches calls between cellular and Wi-Fi
BridgePort Networks (Chicago, IL)	Software on cellular networks allows Wi-Fi devices to make phone calls
Kineto Wireless (Milpitas, CA)	Cellular-network controller allows cell-phone users to roam between home and business Wi-Fi networks
Motorola (Schaumburg, IL)	Dual-mode cellular and Wi-Fi mobile phone
OnRelay (Leatherhead, Surrey, England)	Software turns mobile phones into wireless extensions of office desk phones
Proxim (Sunnyvale, CA)	Next-generation Wi-Fi hardware enables more secure and higher-quality voice calls
Vocera Communications (Cupertino, CA)	Hands-free, voice-controlled system using wireless badges allows workers to communicate via Wi-Fi

HARDWARE

A Chip Worth Remembering

First magnetic RAM product raises hopes for "instant-on" computing



After years of development, this Motorola MRAM chip will hit the market this fall.

Flip on your PC or laptop, and start waiting. The reason you need to boot up—loading software from your hard drive into your random-access memory (RAM) chip—is that most electronic computer memory requires power to keep data intact. Take away the power, and the memory evaporates. For years, researchers have tried to develop fast and cheap memory that stores data as magnetic orientation, which stays fixed whether or not the power is on. Now, an early version of this technology—called magnetic random-access memory, or MRAM—is moving into production.

The MRAM chip, built by Motorola, holds only four megabits of data and is expensive, which means its first applications are likely to be in high-end security systems and gaming machines, where small amounts of crucial code could be stored without fear of loss. But by the end of the decade, MRAM chips may be suitable for gadgets like digital cameras and handheld computers, says Saied Tehrani, Motorola's technology director for MRAM in Tempe, AZ. Motorola says it is working with several customers to improve prototypes of its first-generation chip before starting full-scale production late this year.

Researchers, including those at Motorola and IBM, have been working on MRAM for more than a decade but kept encountering the same problem: recording information magnetically on one memory cell tended to disturb the magnetic orientation of its neighbors.

Motorola's solution is a two-step data-writing method that effectively isolates bits from one another. Bob Merritt, an analyst at Semico Research in Phoenix, calls the Motorola advance "a substantial breakthrough."

THE ATTRACTION OF MRAM

COMPANY	STATUS
IBM/Infineon Technologies (Armonk, NY/Munich, Germany)	Joint venture in France, which has delayed MRAM production until at least late 2005
Motorola (Schaumburg, IL)	Commercial MRAM production by late 2004
NEC/Toshiba (Tokyo, Japan)	MRAM joint venture, which has prototypes but no commercialization plans so far
Philips Electronics/STMicroelectronics (Eindhoven, Netherlands/Geneva, Switzerland)	Collaboration with Motorola to develop denser, higher-capacity MRAM chips

It might be a decade before the technology is ready for PCs, but one intermediate goal is replacing the flash memory used in digital cameras and cell phones. Unlike RAM, flash memory retains data when the power is off, but it's expensive, slow, and too bulky to accommodate the memory demands and size constraints of next-generation devices. Motorola's MRAM chips are 1,000 times faster at storing new information than flash memory, so they could, for example, record digital-camera images more quickly, eliminating the delay before the next picture can be taken. While it remains to be seen whether Motorola will deliver an instant-on computer, its MRAM chip is an important first step. **Russ Arensman**

SOFTWARE

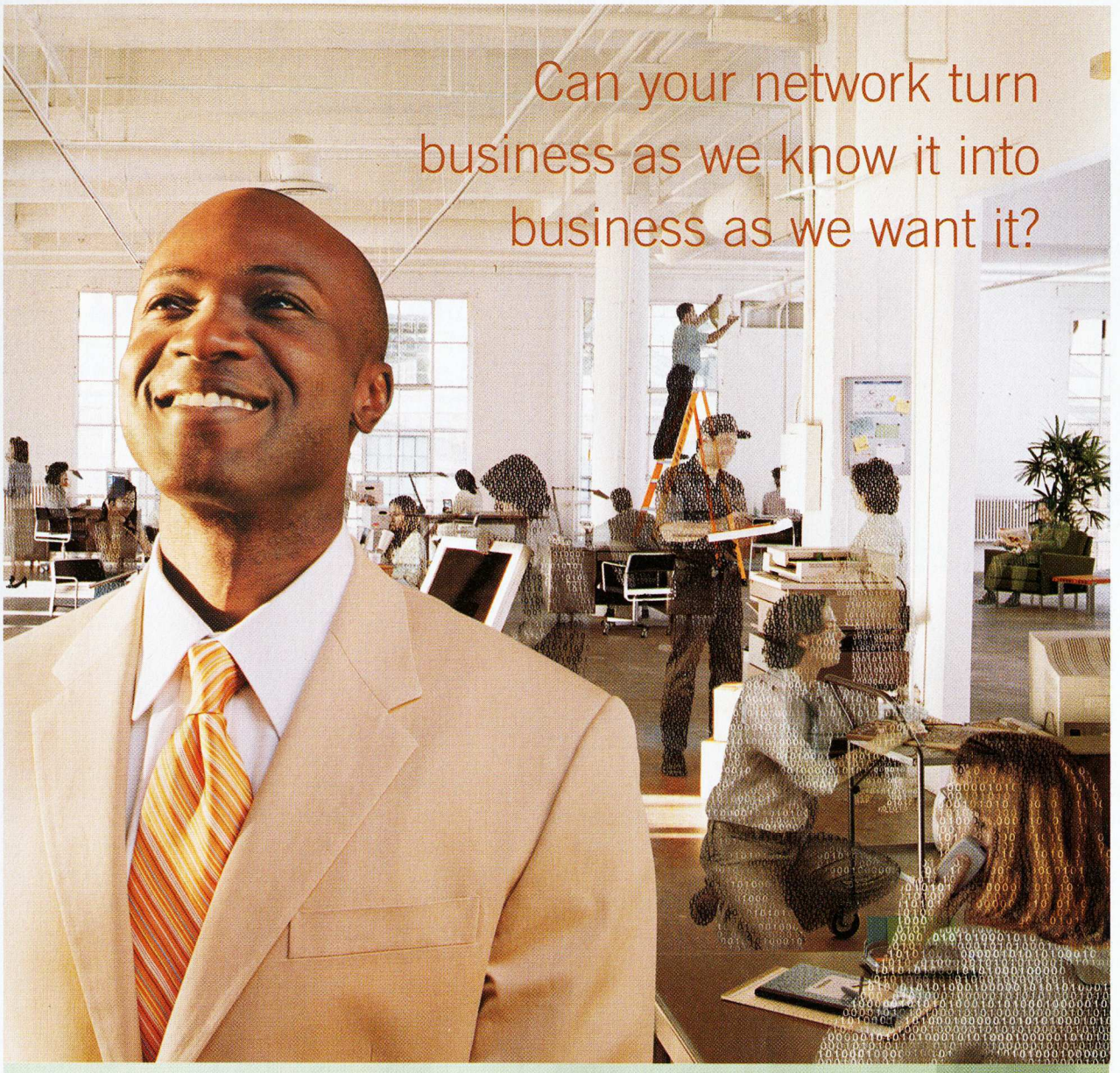
TRACKING OPEN-SOURCE'S ORIGINS

The open-source software movement—in which programmers freely share and build on each other's work—has successfully churned out everything from operating systems to photo editors. But there's a hitch. Sometimes a program's open-source components turn out to be governed by conflicting licenses. A $3 billion suit filed against IBM in March 2003 by software maker SCO Group—which claims IBM contributed code owned by SCO to the open-source Linux project—is just the most glaring example of the potential dangers.

But a solution is emerging. A Chestnut Hill, MA, company, Black Duck Software, has built software that reviews open-source programs, flagging licensing and potential copyright infringement problems. Black Duck's program compares a new piece of open-source software to thousands of existing, well-documented open-source programs. If it finds any matching code, it can tell users whose permission must be obtained—or who must be paid a licensing fee—before the new code can be released. And that's critical for stopping potential litigation, says Ted Schadler, an analyst at Forrester Research. "It has become very important to do an inventory," he says. "Black Duck's technology will tell you what [code] you are running. It's very effective."

Black Duck launched its software—the only system of its kind so far, says founder and CEO Doug Levin—in January 2004. If it gets off the ground, the software could help keep disputes from derailing the open-source movement—and depriving businesses and consumers of a low-cost alternative to software from the likes of Microsoft, Adobe, and Oracle. Wade Roush

COURTESY OF MOTOROLA



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A doctor demonstrates the use of a handheld device that administers magnetic pulses.

MEDICINE

Zapping the Blues

Magnetic therapy for depression enters widespread trials

Every year, clinical depression afflicts more than 18 million Americans, many of whom don't respond to conventional antidepressants like Prozac and Zoloft. But a promising new type of therapy is gaining wider use. The technique, called "transcranial magnetic stimulation," uses pulses of magnetic energy to induce electric currents in specific brain regions. While no one knows exactly why it works, researchers say the treatment can alleviate depression.

Magnetic brain stimulation has been used experimentally for years. Mark George, a neurologist and psychiatrist at the Medical University of South Carolina in Charleston, SC, says that in a number of limited trials, the technique helped severely depressed patients—though modestly and for short periods. These early results have led to government approvals in Israel and Canada. But magnetic therapies have only recently entered large-scale human testing in the United States. A new study, launched in early 2004 and involving hundreds of patients at numerous centers, "should be pivotal" in gaining the U.S. Food and Drug Administration's approval for the therapy in one to two years, says George. "It would be surprising if the therapy didn't prove effective," he adds.

A doctor typically holds a powerful magnet over the frontal regions of the patient's skull and delivers magnetic pulses for a few minutes a day, over the course of a few weeks. The treatment alters the biochemistry and firing patterns of neurons in the cortex, the part of the brain nearest the surface. Preliminary research indicates that the treatment affects gene activity, levels of neurotransmitters like serotonin and dopamine, and the formation of proteins important for cellular signaling—any of which could play a role in alleviating depression. What's more, magnetic stimulation seems to affect several interconnected brain regions, starting in the cortex and moving to the deep brain, where new cell growth may be important in regulating moods.

One problem: doctors can't be sure they are stimulating the same brain regions from patient to patient, or from session to session. A system developed by Malvern, PA-based Neuronetics is part of the new trials; it uses state-of-the-art magnetic materials to generate pulses efficiently and a positioning system that supports the magnet and records its location in three dimensions. That means more repeatable treatments and clearer study results, says Bruce Shook, Neuronetics' president.

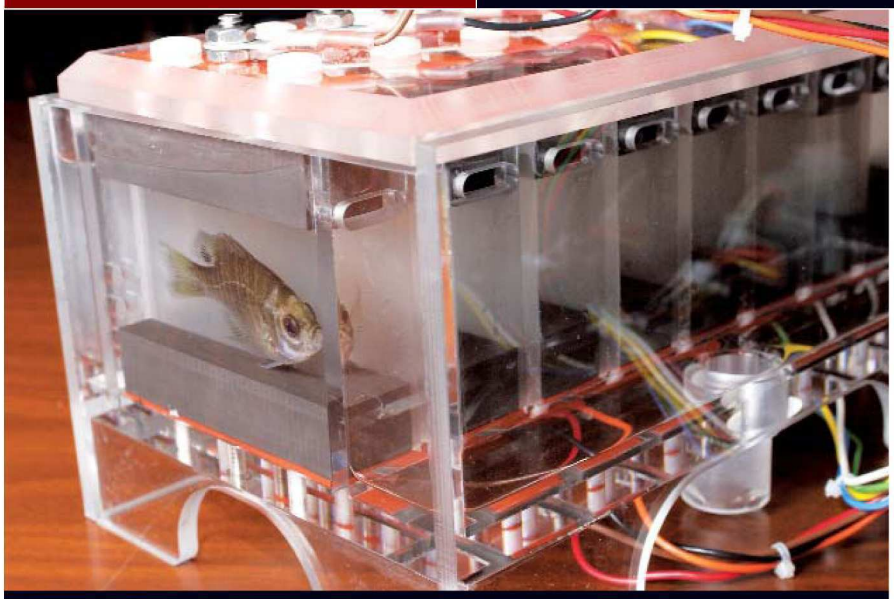
Researchers are beginning to understand how the therapies affect patients. Columbia University psychiatrist Sarah Lisanby is investigating a type of magnetic therapy in which seizures are induced under anesthesia. She is comparing its effects to those of electroconvulsive therapy, in which electrodes on the head provide electrical stimulation. In addition to noting effects on brain cells, she has found that magnetic seizure therapy produces fewer side effects, such as memory loss, than electroconvulsive therapy. "Activating these pathways in real time, we're learning a lot about the brain circuits involved," says Lisanby. And that allows doctors to hone the therapy by adjusting location, intensity, and pulse frequency.

One of the chief remaining questions is whether the positive effects of brain stimulation can be sustained. "It will take a few years to know how effective it is in patients" over the long term, says René Hen, a Columbia neurobiologist. But meantime, magnetic stimulation is attracting much attention from those trying to fight depression. **Gregory T. Huang**

LEADERS IN MAGNETIC BRAIN-STIMULATION THERAPIES

RESEARCHER/ORGANIZATION	PROJECT
Mark George, Medical University of South Carolina (Charleston, SC)	Imaging the brain and improving techniques for treating depression
Leon Grunhaus, Sheba Medical Center (Tel Hashomer, Israel)	Conducting clinical trials of depression treatments
Sarah Lisanby, Columbia University (New York, NY)	Conducting clinical trials with magnetic seizure therapy and studying biochemical mechanisms in the brain
Bruce Shook and Mark Demitrack, Neuronetics (Malvern, PA)	Developing more efficient and reliable hardware

COURTESY OF THE COLUMBIA UNIVERSITY MAGNETIC BRAIN STIMULATION LABORATORY



A bluegill fish's reaction to toxins is measured by electrodes in a chamber.

SENSORS

Swimming Sentinels

Fish enlisted in protecting water supplies from toxins

A high-tech ichthyological version of a canary-in-the-coal-mine warning system is nearing market. It's a system that monitors fish behavior as an early general warning of water purity problems. The system is being tested in several places, including New York City's reservoir system, ahead of commercialization later this year.

The system, developed at the U.S. Army Center for Environmental Health Research at Fort Detrick, MD, uses bluegill fish to detect a broad range of toxic chemicals. It doesn't look for anything specific; it detects anything that would stress a fish, from chlorine to cyanide. Each fish serves two-week tours of duty inside a plastic chamber containing two electrodes. The electrodes sense electrical signals from the fish's muscle movements. During an initial calibration period, software learns an individual fish's normal breathing rate and depth, gill movements, and overall body activity. During water monitoring, software detects departures from normal measurements, which can indicate the fish is stressed.

The advantages of using a fish is that it's a 24-hour warning system that can call early attention to a broad range of problems, allowing officials to shut down a water system as a precaution. While the system cannot determine what's bothering the fish, it does provide a general alarm, says the director of the monitoring program, William van der Schalie, an army toxicologist. "Traditional sensors may focus on one particular chemical. A fish biomonitor rapidly detects toxicity from a wide range of toxic chemicals and pesticides. It will tell you there's a problem to look further into," he says.

In testing by the U.S. Environmental Protection Agency in Cincinnati, OH, the system worked well, says Roy C. Haught, chief of the EPA's water quality management branch. "Any time there's a change in water quality, the fish detect it immediately," Haught says. In the case of New York City, the system has been installed for homeland security purposes, to provide an early warning of chemicals introduced into the water supply. The system will be released commercially late this year by Intelligent Automation of Poway, CA. In the meantime, it needs refinement to weed out false alarms. As Haught puts it, "We don't want to be crying wolf every time a fish coughs." **David Talbot**

VENTURE CAPITAL

SPINOFF DOCTORS

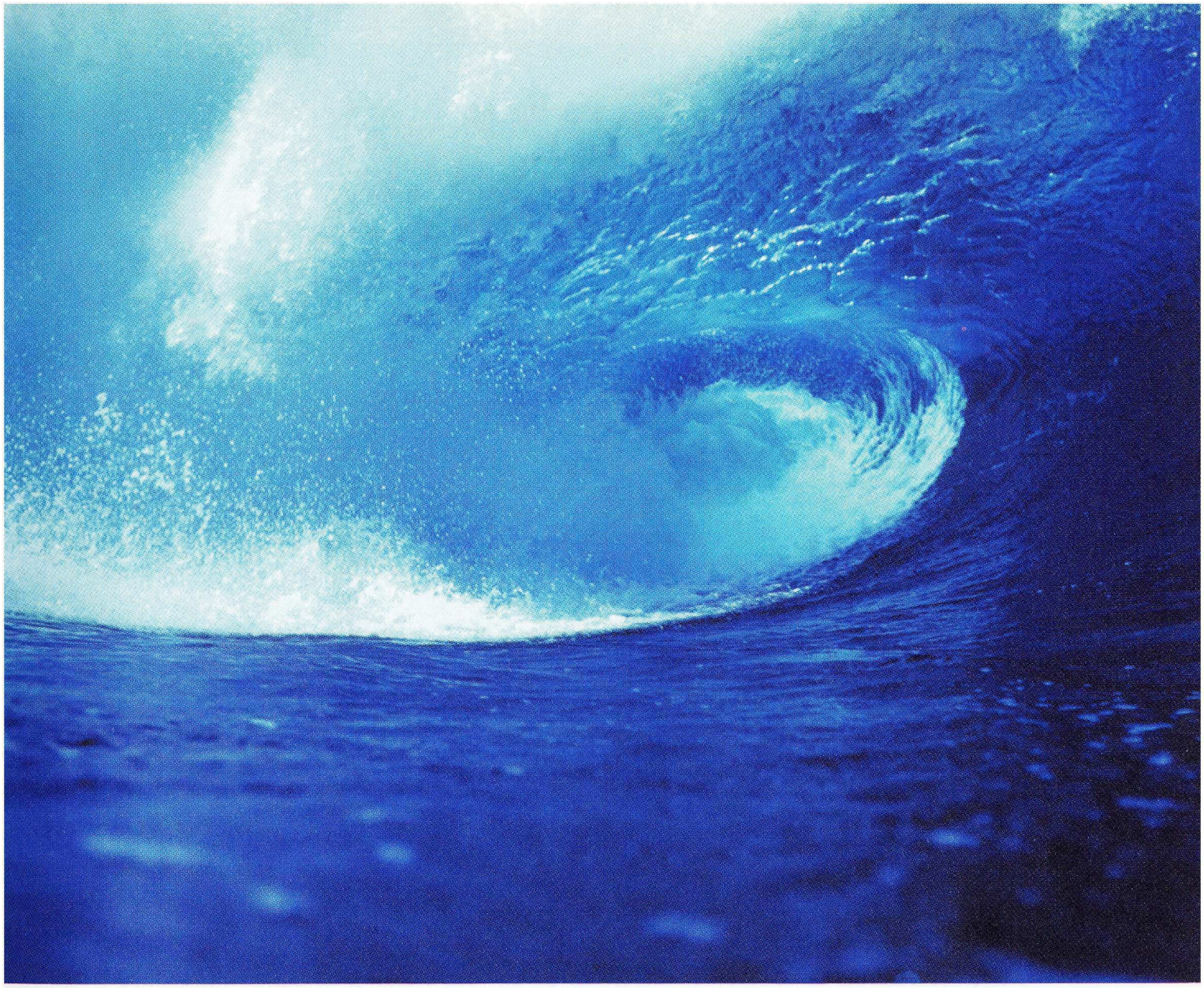
A Lucent Technologies venture capital spinoff—initially launched to commercialize underused technologies from the company's labs—has secured sole rights from British Telecom and Philips Electronics to do the same job for them that it's doing for Lucent.

An early success made this leap possible. In 2002, the Lucent spinoff, New Ventures Partners of Murray Hill, NJ, sold one of its first companies—Celiant, which took a radio amplification technology out of Lucent's Bell Labs and developed it for next-generation cell-phone networks—for $470 million. And that meant New Ventures Partners had cash and credibility "to talk to other corporations and say, 'We'll put up the capital and do this for you too, and in return, we'd just like to have exclusive access to your labs,'" explains managing partner Andrew Garman.

British Telecom was the first to grant this access, in return for benefits such as a part of any future sale or public offering of resulting companies. In 2003, New Ventures Partners launched four new companies based on technologies from BT's labs. One was Microwave Photonics, a Los Angeles concern developing a radio-over-fiber technology that makes it possible to expand cell-phone networks without adding base stations. Maurizio Vecchione, Microwave Photonics' president and CEO, says New Ventures went well beyond the role of the traditional venture capital firm—most importantly, negotiating licensing agreements with BT that didn't burden the startup with royalty payments.

Late last year, Philips entered into a similar agreement with New Ventures. While other companies, such as Arch Venture Partners in Chicago, specialize in building startups around technologies from large R&D organizations, New Ventures "probably has the most advanced set of processes and the deepest network of contacts," says Henry Chesbrough, a professor in the Haas School of Business at the University of California, Berkeley. British Telecom and Philips are now tapping that network. Wade Roush

COURTESY OF THE U.S. ARMY CENTER FOR ENVIRONMENTAL HEALTH RESEARCH



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2004 AWARDS

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Nominations are now open for the 2004 edition of the TR100, *Technology Review*'s list of 100 young people whose contributions to emerging technologies are poised to profoundly influence our world. We're seeking the best young innovators in such fields as biotechnology, computing, energy, medicine, nanotechnology, telecommunications, and transportation.

Nominees should not turn 35 before October 1, 2004, and their work should exemplify the spirit of innovation. *Technology Review* will showcase all 100 in a special October 2004 issue and recognize them at a gala awards celebration at our Emerging Technologies Conference, September 29-30, 2004.

The deadline for nominations is March 31, 2004.

To Nominate Visit:

www.technologyreview.com/tr100/nomination

Mind the Gap

A TRUE ECONOMIST, THE JOKE GOES, WOULD never bother to pick up a $10 bill on the sidewalk because in an efficient market, instant, riskless profit is impossible. Of course, markets are far from efficient, and an entrepreneur would not only scoop up the sawbuck but also scheme about where to find more. Startup companies are ventures whose entire existence is based on exploiting a gap in the market—an inefficiency that existing companies have failed to identify and pursue for profit. Potential investors attempt to assess the size (or even existence) of a startup's designated gap and whether the company is truly poised to take advantage of it.

I recently ran across a fascinating case of attacking such a gap in London, England-based SwapitShop, an enterprise dedicated to creating a universal currency for children. As Jonathan Attwood, SwapitShop's CEO, explains, children have tremendous economic influence via their parents, who purchase endless quantities of toys, food, and entertainment on their behalf. Yet kids themselves generally have very little ready cash. Guiding their economic influence is big business, and marketeers constantly strive to "incent" (i.e., bribe) kids to demand the games, TV programs, and sugary snacks that they sell.

Attwood finds huge inefficiencies—and hence opportunities—in the ways that these incentives are currently meted out. Inserting a Spider-Man figure in every box of Frosted Flakes costs millions, he explains, and of course many children may not like Spider-Man, or action figures at all. His solution: give kids Swapits, a virtual currency redeemable for merchandise on the SwapitShop Web site. Swapits are distributed as coded numbers printed on coupons or product packages. Printing 100 Swapits on the inside flap of a cereal box costs next to nothing, says Attwood, and kids can get things they actually want.

SwapitShop profits from these transactions by selling its currency to, say, a cereal company, typically for a few tenths of a penny per Swapit. SwapitShop then spends about one-third of its take on new merchandise, ensuring a broad range of gettable goodies and preventing Swapit currency devaluation. The remaining two-thirds is gross profit—not a bad ratio at all!

SCORECARD: SWAPITSHOP

ELEVATOR PITCH	Monetize the economic influence of children worldwide
FUTURE VISION	"Swapits" will become a fungible kids' currency
CEO'S INSOMNIA	Running out of money before building a critical mass of end users
LEG UP	Strong brand recognition in the U.K.; solid, well-known customers

The site began with another idea, though, that it continues to promote. Kids can also obtain Swapits by auctioning off toys, CDs, Pokémon cards, and other closet clutter to obtain something more desirable: hence the "swap" moniker. Children post descriptions of items for auction on SwapitShop's site. When a bidder has won an item, the seller mails it to SwapitShop, which forwards it to the buyer. Sellers, meanwhile, redeem their Swapits for new or auctioned items on the Web site.

Taking a commission on auctioned items, as eBay does, isn't particularly useful to SwapitShop, since Swapits aren't worth anything outside the company's own Web site. However, Attwood and his founding partner, Emily Elton, realized that the outflow of parcels from redeemed Swapits has made them one of the United Kingdom's largest direct mailers to children. Now every package carries coupons and other marketing literature along with the purchased item. Attwood claims that the revenue from direct marketing covers the cost of processing the merchandise in the first place—plus a small profit margin.

Attwood and Elton excel at squeezing every pound of profit from what began as the simple idea of swapping old toys. In addition to the sales of Swapits to consumer products makers and the fledgling direct-marketing business, they've created a division to survey and test-market third-party products to SwapitShop kids, obtaining valuable market data from a group that is traditionally difficult to reach. SwapitShop charges anywhere from several hundred to tens of thousands of pounds for these services, but the participants are paid, of course, in Swapits.

The duo's obsessive pursuit of efficiency and profit has enabled the company to survive a grueling economy with minimal cash infusions. To date it's raised less than $750,000 from angel investors and is squeaking by at more or less breakeven with five full-time employees. Nonetheless, it's managed to expand its user base to more than 100,000 children and boasts Disney, Vivendi, Sainsbury's, Nestlé, and the U.K. government as paying customers.

Although now operating solely in the United Kingdom, SwapitShop has major ambitions for its currency. Attwood foresees Swapit cards that operate like debit cards, redeemable for discounts or merchandise in participating stores around the world. He pictures Swapits as gifts, allowances, and homework incentives—a universal motivator for kids.

Ultimately, the Swapit currency may become the mechanism for monetizing the economic influence of children. That's a market gap that may be worth a fortune to the companies that can successfully exploit it, and to the investors lucky enough to pick a winner. Then again, the gap, like the economist's ten-spot, may be just an illusion.

Joe Chung cofounded Cambridge, MA-based Art Technology Group. Neither he nor *TR* holds any financial interest in the companies profiled nor endorses them as investments.

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***Source: KPMG 2002 – G7 (excludes Russia) 12-industry average.**

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Search Beyond Google

Google's search techniques have tamed the Web and earned the company a massive following, not to mention a fortune in ad revenues. But now the search business is priming for another big leap—with Microsoft and a pack of startups readying new technologies and vying to dethrone the reigning king.

By Wade Roush

Illustration by Tim Bower

If employees at Google are anxious about the future, you wouldn't know it from a visit to the company's headquarters. Since last fall, when talk of an initial public offering got investors salivating, the organization has been under unusual scrutiny: some observers have called it "the hottest company on the planet," while others claim it's a business in leaderless disarray, with competitors crowding in and major customers on the verge of defection. But the Google complex in Mountain View, CA, is as outwardly carefree as any college campus. The main lobby is a study in shagadelic kitsch, with a baby grand piano, a spinning party light, and a row of neon-bright lava lamps arranged in the same blue-red-yellow-blue-green-red sequence as the company's familiar logo. The cafeteria pulses with rock music, shouted conversation, and the sounds of geeks slurping free gourmet food. Upstairs, in the cubicle farms, programmers chitchat across walkways littered with toys, Segway transporters, and the occasional canine.

It's only when I sit down in a quiet conference room with Google director of technology Craig Silverstein that the giddy dot-com mood turns more serious. Now that companies like Google and Internet ad agency Overture have demonstrated that displaying subject-specific paid ads alongside the results on a search page is a real moneymaker—contributing to an estimated $2 billion in industrywide revenues in 2003—a pack of wannabes are investing in search software they say will give users more pertinent results than Google's, faster. I ask Silverstein whether Google's famous focus on better technology will keep it ahead of all that competition. His answer is circumspect.

"It's very easy to move from one search engine to a better one," he says. Google pays hundreds of researchers and software developers, including more than 60 PhDs, to man the front lines in this technology war, explains Silverstein, who is himself on extended leave from his doctoral studies in computer science at Stanford University. But he acknowledges that's no guarantee of victory. "We hope the next breakthrough comes from Google—but who knows?"

Who knows, indeed? According to Reston, VA-based research firm comScore, Google has a large lead over its rivals in U.S. audience share, accounting for 77 percent of all searches in August 2003 (including searches conducted at AOL and Yahoo!, which used the Google search engine). But in the search industry, innovation is a wild card. "In 1999, you could have said that AltaVista had pretty much finished off the search market," notes Whit Andrews, a research director at technology advisory firm Gartner. "In 1997, it was Inktomi. In 1995, it was Yahoo!. You never know in the search business when there's somebody down the street who is going to make you look like yesterday's news."

Google is vulnerable partly because it has few of the infrastructural advantages, like AT&T's once exclusive ownership of most of the telephone network or Microsoft's control of PC operating systems, that typically help to perpetuate dominance. (Indeed, press reports in January indicated that Yahoo! might soon drop its relationship with Google and turn to its own search technology.) And the company's claim to fame—the ability of its search algorithms to find the most relevant results, based on their popularity—may be growing stale. "When Google first launched, they had some new tricks that nobody else had thought about before," says Doug Cutting, an independent software consultant who wrote some of the core technology behind search engine Excite and has designed search tools for Apple Macintosh computers. But plenty of other search engines now offer intriguing alternatives to Google's techniques, Cutting believes.

For example, there's Teoma, which ranks results according to their standing among recognized authorities on a topic, and Australian startup Mooter, which studies the behavior of users to better intuit exactly what they're looking for. And then there's the gorilla from Redmond: Microsoft is turning to search as one of its next big business opportunities. Its researchers are devising a new operating system that melds Google-like search functions into all Windows programs, as well as software that scours the Web for definitive answers to questions you phrase in everyday English. Meanwhile, Yahoo! launched its own research laboratory in January, and Cutting himself is building an open-source alternative to Google *(see "Keeping an Eye on Google," p. 40)*. "Nowadays," he says, "I'm not convinced [Google is] markedly better."

Whichever technology hooks tomorrow's Web surfers, its builder will earn enormous influence—and handsome profits. Some 550 million search requests are entered every day worldwide (245 million of them in the United States). By 2007, the paid-placement advertising revenue generated by all these searches will reach about $7 billion, says Piper Jaffray analyst Safa Rashtchy. Yet surveys indicate that almost a quarter of users don't find what they're looking for in the first set of links returned by a search engine. That's partly because the precious needles of information we seek are buried under a haystack that grows by some 60 terabytes every day. And it's why brutal competition in the search industry is certain to continue, especially as search companies usher in a host of advanced technologies, such as natural-language processing and machine learning. "Over the next five to ten years," says Rashtchy, "we could see massive improvements that provide orders-of-magnitude increases in relevancy and usage." And it's the competition to deliver those improvements—much more than the success or failure of Google's rumored IPO, expected by many to happen this spring—that is likely to determine how we will be navigating the Web a few years from now.

PULLING RANK

By nature chaotic and decentralized, the Web screams out for tools to help people hunt down documents no matter where they reside. Say you want information on treatments for scurvy in the 18th century: without a search engine, you have no way of knowing that the data you need is stored only in places like a cryptically named file (www.jameslindlibrary.org/trial_records/17th_18th_Century/lind/lind_kp.html) on a server at the library of the Royal College of Physicians in Edinburgh, Scotland.

When you type "scurvy" into a search box at Google or MSN or Ask Jeeves, however, you're still not touching the actual file at the Royal College. You're merely rifling through the search company's index of the Web—a huge list assembled by software "spiders" that crawl through thousands of pages every second, copying keywords, phrases, titles and subtitles, links, and other descriptive information. Once a fragment of information lands in the index, it's usually compressed, assigned a "weight" or importance, and stored in a database for quick retrieval. The

DEBRA MCCLINTON


"We hope the next breakthrough comes from Google—but who knows?"
GOOGLE DIRECTOR OF TECHNOLOGY CRAIG SILVERSTEIN

search terms you enter are compared against this index, and links to pages that contain one or more of your terms are displayed in order of relevance.

How a search engine determines that relevance is the secret sauce. Google rocketed to prominence in 1999 largely due to PageRank, an algorithm invented by founders Larry Page and Sergey Brin that was the first to capitalize on the massive interlinking of Web pages. Each link is, in effect, a vote made by the author of one page for the contents of another. Page and Brin realized that if their index were big enough, they'd be able to assess a page's importance by counting the number of other pages that linked to it. They took other factors into account as well, such as the pertinence of the text surrounding the links and the linking pages' own popularity. But their groundbreaking insight was that the Web is a giant popularity contest—and that the most-cited pages will probably be the most useful. The technique worked fiendishly well, and Web users voted with their clicks. Between June 2000 and January 2004, former top dog AltaVista, which ranked results largely according to the number of times a page mentioned the user's search keywords, dropped from eighth place in overall Web traffic rankings to 61st, while Google climbed from near-invisibility to fourth place, according to data from research firms Media Metrix and Alexa. Google has so pervaded the Web that its very name was selected by the American Dialect Society as the most useful new word of 2002.

Despite its advantages, PageRank has a few flaws. Just as earlier search engines could be fooled by pages peppered with thousands of keywords in "invisible" white-on-white type, an unscrupulous site owner who wants his Web address to appear higher in Google's search results can easily publish thousands or even millions of junk pages that contain links to his site, artificially raising its rank. (Google says it has ways of counteracting such attacks, but won't discuss them.) The same loophole in PageRank allows "Google bombing"—a recent phenomenon in which bloggers make a humorous or political point by creating so many links to a given site that it comes up first when users type a specific term into the Google search box. Google bombers protesting the war in Iraq, for instance, managed to make George W. Bush's White House biography the first-ranked result under "miserable failure."

More bothersome to some critics, however, is PageRank's obsession with fame. A legitimate page that matches a Google user's search terms perfectly may get buried in search results simply because there aren't enough other pages pointing to it, notes Daniel Brandt, a Web developer who runs a critical site called Google Watch. A page's relevance to an individual user, Brandt and other critics argue, may depend on more than its popularity. "Just because the rest of the planet thinks that this is the number one travel site doesn't mean it is the number one travel site for you," says Liesl Capper, founder and CEO of Sydney-based upstart Mooter, who believes she just might have a better way.

A STARBURST OF IDEAS

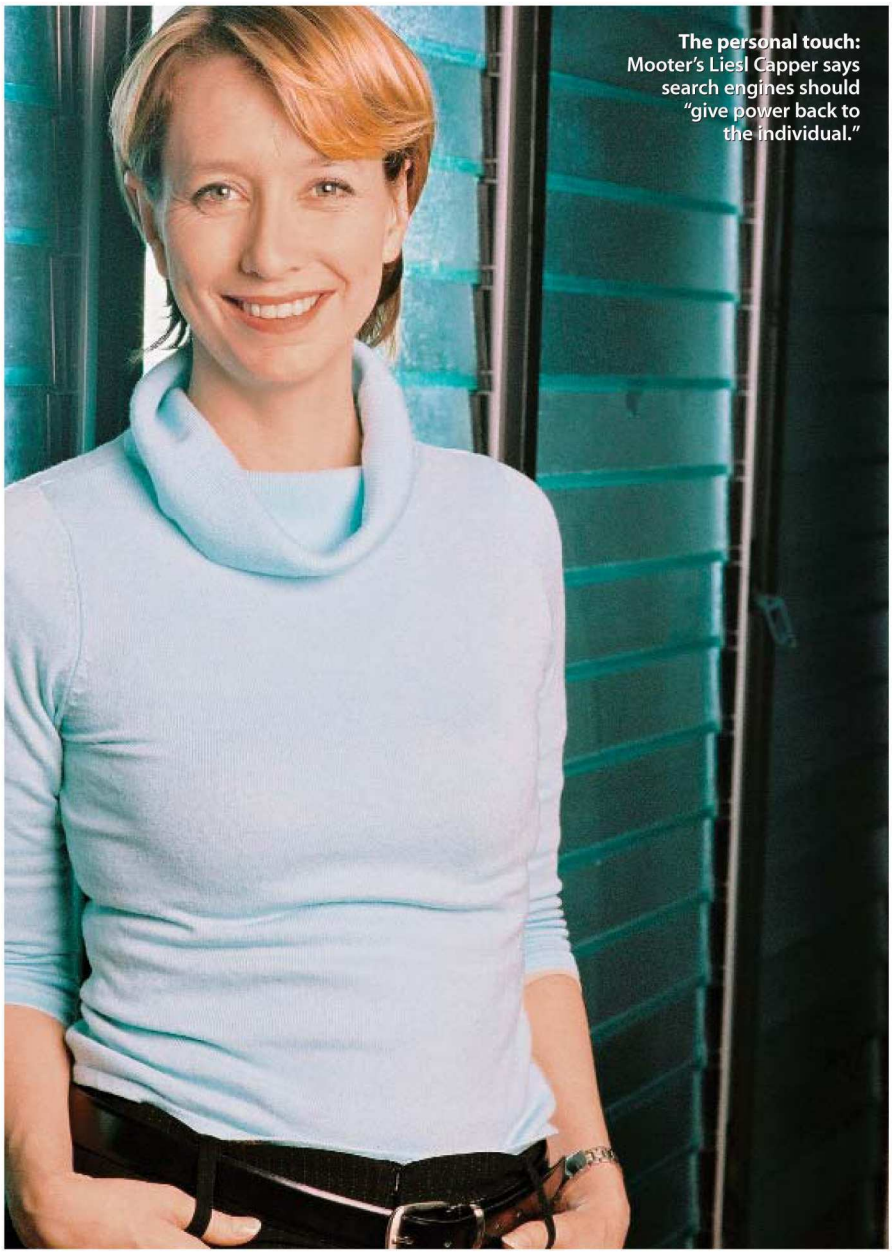
I'm lunching with Capper on a brilliant early-winter day in San Francisco. She's in town to call on potential investors and customers. "People who control the flow of information have a subtle but pervasive power," she tells me earnestly. "Someone has

PUTTING A STAMP ON SEARCH RESULTS

Enter the same search term into ten different search engines, and you're likely to get ten conflicting sets of results. That's partly because the search companies' spiders crawl different subsets of the Web; but more importantly, it's a reflection of the unique principles at work in each company's ranking algorithms. Here's how three search engines handle the term "**stamp collecting**."

	ASK JEEVES/TEOMA	GOOGLE	MOOTER
1	American Philatelic Society www.stamps.org	Coin and Stamp Collecting (About.com) collectstamps.about.com	Stamp Link—Philately, Stamp Collecting's Best Site in Its Category www.stamplink.com
2	Joseph Luft's Philatelic Resources on the Web www.execpc.com/~joeluft/resource.html	Joseph Luft's Philatelic Resources on the Web my.execpc.com/~joeluft/resource.html	Warragul Philatelic Society (Stamp Collecting) www.bbsc.vic.gov.au/i519.htm
3	Linns.com: The website of the world's largest weekly stamp newspaper—Linn's Stamp News www.linns.com	American Philatelic Society www.stamps.org	Postal history, philatelic covers and stamps for sale www.the-stamp-collector.com
4	Stamp Link—Philately, Stamp Collecting's Best Site in Its Category www.stamplink.com	BNAPS Stamp Collecting for Kids www.bnaps.org/stamps4kids	Great Britain Philatelic Society www.gbps.org.uk
5	Philatelic.Com www.philatelic.com	Linns.com: The website of the world's largest weekly stamp newspaper—Linn's Stamp News www.linns.com	Stamp Collecting, Philately, Stamp Auction www.simonandrews.com
	The top-ranked page has the highest "authority"—essentially, the most links—among communities of Web sites about stamp collecting. It's validated by references from resource pages (link collections from experts and enthusiasts—in this case, stamp collectors) and link popularity measurements similar to Google's. The runner-up, Joseph Luft's Philatelic Resources, has fewer and less qualified referrals from experts on the subject.	Google officials won't discuss how the Google engine arrives at rankings for specific sites. Patent documents and published papers, however, show that Google ranks pages according to how often other pages link to them. Google also takes into account such factors as the relevance of the referring pages and the text surrounding the links. Presumably, collectstamps.about.com is the most cited page on this subject in Google's index.	Mooter first groups results into clusters or themes. The pages shown above appear in the "philatelic" cluster, ranked according to how frequently the search keywords and the cluster name appear on each page, among other factors. Mooter "learns" the user's intent by noting which clusters and pages are clicked on, and reranks the results to reflect the apparent pattern of interest.

SOURCES: ASK JEEVES, GOOGLE, MOOTER. RESULTS CURRENT AS OF JANUARY 5, 2004 (ASK JEEVES, GOOGLE), JANUARY 13, 2004 (MOOTER).



The personal touch: Mooter's Liesl Capper says search engines should "give power back to the individual."

to hold that power, and it is important that the people who do are those who consciously try to have a positive impact, and who give power back to the individual." Mooter aims to do that by making Web searches easier and more personal. Capper grew up in Zambia, studied psychology in South Africa, and founded a chain of early-childhood-development centers before emigrating to Australia in 1997 and choosing search technology as the place to make her next impact. She set up shop in downtown Sydney and hired Jondarr Gibb, an experienced software architect, and John Zakos, a graduate student writing his Griffith University doctoral thesis on the applications of neural-network theory to Internet searches.

The three have mixed their ideas on psychology, software, and neural networks to create a ranking algorithm that learns from the user as a search progresses. Before dumping a long list of links on a user, Mooter analyzes the potential meanings and permutations of the starting keywords and, behind the scenes, ranks the relevance of the resulting Web pages within broad categories called clusters. The user first sees an on-screen "starburst" of cluster names. A search on the name Paul Cézanne, for example, yields clusters such as *art*, *artists*, *Cézanne*, *France*, *galleries*, and *famous paintings*. That's the psychology part. "When you do a traditional search, you get your millions of results, and your mind does a conceptual grouping," says Capper. "But our minds are hard-wired to process only three to five kinds of information at once. We decided not to override that but to work with it."

Then comes the learning part. To develop a more precise understanding of what the user is probably looking for, the Mooter engine notes which clusters and links get clicked and uses that information to improve future responses. Suppose a user enters the term "dog," clicks on a cluster called "breeds," and then spends a lot of time looking at sites about Schnoodles (a popular Schnauzer-Poodle mix). When the user clicks on a new search result, Mooter will personalize the ranking to reflect this apparent pattern of interest, which might, for example, lead to sites about "dogs" plus "breeds" plus "Schnoodles" appearing higher. A refined set of results appears on every page; the engine continues to adjust the rankings based on the user's behavior.

The whole idea is to give people the results they want in as few clicks as possible. "Two clicks and we already have a very good idea of where you're heading," says Capper. When Mooter's beta site debuted last October, Capper didn't expect it to be noticed outside Australia. But traffic from around the world has been so heavy, she says, that the company has had to install more Web servers to keep the service running.

Spend much time talking to search-industry insiders and you'll realize that there are almost as many ways to rank search results as there are pages on the Web. Google's supposed overreliance on popularity was one of the inspirations behind Teoma (pronounced tay-*o*-ma), founded in 2000 by computer scientist Apostolos Gerasoulis and colleagues at Rutgers University in New Jersey. Teoma's search software now powers Ask Jeeves, the number six search site. Google "looks at the structure of the Web, but that method doesn't go down to the next level," says Paul Gardi, Teoma's senior vice president for search. "When you get down to the local level, you will find that links cluster around certain subjects or themes, very much like communities." For instance, pages on "home improvement" don't simply link upward to more popular pages; they also tend to link to each other, forming circles around prominent sites like Hometime.com, Homeideas.com, and BobVila.com.

The Rutgers scientists designed Teoma (Gaelic for "expert") to find those subject-specific communities and exploit their wisdom. Before the Teoma engine presents the results for a given set of keywords, Gardi explains, it identifies the associated

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KEEPING AN EYE ON GOOGLE

WAL-MART, MCDONALD'S, MICROSOFT: a handful of companies are so dominant in their markets that almost everything they do is condemned by someone as an abuse of power. Now Google has joined that exclusive club. As the proprietor of the Internet's most popular search engine, Google has become the de facto gatekeeper of the Web—with the ability to make or break a site simply by moving it up or down a few notches in its search rankings. And while that hasn't affected Google's pristine brand image among hundreds of millions of Internet users, it has some programmers and Web publishers thoroughly riled. "Search engines are an essential part of the Internet now, and yet they're all controlled by private organizations, and their mechanisms are secret," says **Doug Cutting**, an independent software consultant based in Petaluma, CA. "There's a lot of room for these companies to manipulate their services for commercial gain. It's an unhealthy situation."

Cutting's remedy is an open-source search engine, called **Nutch**, that uses ranking algorithms similar to Google's, but with a twist: each search result is accompanied by a link labeled "Explain" that produces a detailed accounting of the various scores and weights that gave the result its rank. Says Cutting, "We want to provide something that will work as a watchdog, so that experts can compare Nutch's results to a commercial search engine's and see whether, for example, somebody is biasing their results toward their advertisers." If all is on the up and up, the results should be roughly the same. Cutting's development of Nutch is being funded in part by Internet ad agency Overture, which was recently acquired by Yahoo!; the new search engine should be publicly available later this year.

Google also boasts a few human watchdogs, including the publishers of Web sites such as **Watching Google like a Hawk** and **Search Engine Watch**. But perhaps Google's most persistent and tendentious critic is **Daniel Brandt**, founder of **Google Watch**. Brandt, who makes his living running a reference site called NameBase.org that collects book and newspaper citations of prominent people, believes Google is too cavalier toward small Internet businesses, which can spend months working to raise their Google rankings, only to vanish back into obscurity whenever Google modifies its ranking algorithms. Google does this mainly to thwart people who game the system to unfairly inflate their status, but the periodic adjustments can also have a devastating impact on legitimate sites who find the rules of search engine success changing in the middle of the game.

After a major reshuffling of the Google rankings in November 2003, Brandt published a tool he called Scroogle; it shows which sites are "missing" from Google's top 100 search results for a given term, compared to the pre-November rankings. Outraged visitors have since boosted Google Watch's traffic tenfold. "The 'Mom and Pop' Web sites were collateral damage that didn't deserve to get whacked," says Brandt. He supports Cutting's Nutch project and believes that a public entity, such as the U.S. Library of Congress, should develop Nutch into a comprehensive, noncommercial search tool to blunt Google's influence.

As a private company, Brandt concedes, Google has the right to use its technology however it wants. But "as soon as their power infringes on the lives and livelihoods of other people," he says, "it's a matter of public concern."

communities and looks for the "authorities" within them—that is, the pages that community members' Web sites point to most often. Teoma tries to verify the credibility of these authority pages by checking whether they're listed on resource pages created by subject experts or enthusiasts, which tend to link to the best pages within the community. It then ranks search results according to how often each page is cited by authority pages.

IBM and other organizations experimented with similar authority-based ranking systems in the late 1990s, but Gerasoulis says their approaches could take hours to slog through all the pages out there. Gerasoulis's proprietary technique does the same thing in about a fifth of a second. Ask Jeeves dumped its previous search provider and switched to Teoma's technology in 2001, and its query volumes jumped 30 percent per year in 2002 and 2003.

Hard as it may be to believe when you're looking at a dozen pages of search results, today's search engines ignore most of what is out there on the Internet. Software spiders have difficulty indexing content that is protected behind sign-up forms or stored in databases such as product catalogues or legal and medical archives and only assembled into Web pages at the moment users request it. This so-called Deep Web may amount to as much as 92 petabytes (92 million gigabytes) worldwide, or nearly 500 times the volume of the surface Web, according to the School of Information Management and Systems at the University of California, Berkeley.

Mining the Deep Web is the mission of another fresh face in the search business—Chicago-based Dipsie. "Google and Teoma only index about 1 percent of the documents out there," says Jason Wiener, Dipsie's founder and chief technology officer. Wiener, a self-taught programmer who ran a San Francisco Web development company until the dot-com crash, has spent the last two years building a more nimble crawler, one that can get past forms and database interfaces. Say you're wondering about the standard equipment on a Mercedes 55SL convertible. At Cars.com, drilling down to the page with detailed product information will take about six steps. Dipsie, however, will have indexed the entire Cars.com database in advance, so it can send you to the same page with a single click. "We don't handle anything that requires authentication with a username and password, but we do almost everything else," Wiener says. He claims that by the time Dipsie's search site becomes publicly available this summer, its index will include 10 billion documents—triple the current size of Google's index.

So while Google is still king of the hill, the hill itself is now crawling with competitors with their own bright ideas. "Google knows this," says Gartner analyst Andrews. "They were born at Stanford, and they know there are students in Stanford's classes who are saying, 'Hey, I've got an idea—what if we take this algorithm and stitch it together with that algorithm?' They've got to either hire the young turks or defeat them."

MICROSEARCH

But if there is one software company that knows how to hire young turks and turn their ideas into market-dominating products, it's Microsoft. Name any hot corner of computer science, and the company Bill built is likely to employ at least one or two of the field's leading investigators: after all, the five Microsoft Research labs around the world employ more than 600

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researchers. And when Microsoft smells a big market, it usually moves with full force to stake its claim.

There's nothing blue-sky about Microsoft's forays into information retrieval, the discipline from which the search engine sprang. The company has already won a 97 percent market share in PC operating systems and a 90 percent share in office software; search is one of the last big pieces of the computing landscape that Microsoft does not dominate. And a survey of R&D projects at the company confirms that it sees enhanced forms of search as key to its business growth. As the release of the next version of Windows, code-named Longhorn, grows nearer—a test version will be ready later this year—researchers and product developers are accelerating efforts to make Web searching an integral part of it.

One of the flashiest pieces of software in the works promises to allow you to enter your questions in simple English and get a direct answer back. The company believes search users shouldn't have to worry about selecting the right keywords, linking them together with the right Boolean operators (*and*, *or*, *not*, etc.), and scrolling through page after page of search results. Instead, says Microsoft researcher Eric Brill, search engines should understand and answer questions in natural language.

Take Microsoft Research's AskMSR program, which Brill and his colleagues have been testing on Microsoft's internal network for more than a year. At its core is a simple search box where users can enter questions such as "Who killed Abraham Lincoln?" and, instead of getting back a list of sites that may have the information they seek, receive a plain answer: "John Wilkes Booth." The software relies not on any advanced artificial-intelligence algorithm but rather on two surprisingly simple tricks. First, it uses language rules learned from a large database of sample sentences to rewrite the search phrase so that it resembles possible answers: for example, "___ killed Abraham Lincoln" or "Abraham Lincoln was killed by ___." Those text strings are then used as the queries in a sequence of standard keyword-based Web searches. If the searches produce an exact match, the program is done, and it presents that answer to the user.

In many cases, though, the program won't find an exact match, but only oblique variations on the text strings, such as "John Wilkes Booth's violent deed at the Ford Theater ended Lincoln's second term before it had started." That's okay, too. As its second trick, AskMSR reasons that if "Booth" frequently appears in the same sentence as "Lincoln," there must be an important relationship between them—which allows it to posit an answer, even if it's not 100 percent confident *(see "Q: How Does Question Answering Work?" this page)*. "We are tapping into the redundancy of the Web," explains Brill. "If you have a lot of places where you are somewhat certain that you have found the answer, the redundancy makes it more certain." As the Web grows, so will its redundancy, making AskMSR ever more powerful, Brill reasons. While plans for AskMSR aren't definite, Brill believes the code will see the light of day, perhaps as part of a future Microsoft search engine.

Another Microsoft Research effort is less concerned with how search engines work than with how and when users need information. "Right now, when you want to search for information, you basically stop everything you're doing, pull up a separate application, run the search, then try to integrate the search result into whatever you were doing before," says Microsoft information retrieval expert Susan Dumais. "We are trying to think about how search can be much more a part of the ongoing computing experience."

Toward that end, Dumais is developing a program called Stuff I've Seen that's designed to give computer users quick, easy access to everything they have viewed on their computers. The interface to the experimental program, which will influence the search capabilities in Longhorn, is an always available search box inside the Windows taskbar. Enter a query into the box, and Stuff I've Seen will display an organized list of links to related e-mail messages, calendar appointments, address book contacts, office documents, or Web pages in a single, unified window. One emerging feature of Stuff I've Seen, called Implicit Query, would work in the background to retrieve information related to whatever the user is working on. If you're reading an e-mail message, for example, Implicit Query might display a box with links to the titles and e-mail addresses of all the people whom the message mentions, and to all of your previous e-mail from the sender. To make the software even more useful, Dumais is working on adding an item to the two-button mouse's standard Windows right-click menu that would be labeled "Find me stuff like this" and would search both personal and Web data for information related to a highlighted name or phrase.

AskMSR, Stuff I've Seen, and related projects are all part of a larger shift in technology strategy at Microsoft, one that could position the company to convert hundreds of millions of Windows users around the world to its own search technology, much as it wrested the Web browser market from Netscape back in the 1990s. The crux of this

Q: HOW DOES QUESTION ANSWERING WORK? A: LIKE THIS

Microsoft's **AskMSR** software turns plain-English questions into formal search queries and polls the Web for consensus answers.

1. Question	How many eggs are in a baker's dozen?
2. Rewrite query	"There are" + "eggs in a" + "baker's dozen" "A baker's dozen has" + "eggs" "baker's" + "dozen" + "eggs"
3. Collect search results and filter (for example, ignore results that do not resemble an answer to a "how many" question)	"A dozen usually has 12 eggs, so how many eggs does a baker's dozen have?" "The *Baker's Dozen Cookbook*" "Why are 13 eggs called a baker's dozen?" "13 eggs make a baker's dozen."
4. Extract answers from text and present most likely answers	13 eggs (81 percent likely) 12 eggs (7 percent likely)

SOURCE: MICROSOFT

transformation is the new Windows File System, or WinFS—the very heart of Longhorn. Under the current Windows file system, each software application partitions its allotted storage space into its own peculiar hierarchy of folders. This makes it nearly impossible, for example, to link a chunk of information such as the name of the author of a Word document with the same person's address or phone number in Outlook. WinFS, by contrast, has at its core a relational database: an orderly set of tables stored on your hard drive where all the data on your computer can be searched and modified by all applications using a standard set of commands.

If Longhorn includes tools based on Stuff I've Seen and allows them to communicate directly with a Web search engine, it could create the "single search box" dreamed of by software makers—the gateway to all the information you need, whether inside your PC or out on the network. Gartner's Whit Andrews, for one, is looking forward to Microsoft's new software. "Bring it on!" he says. "I am sitting here looking at my e-mail. If I want to look you up, I've got to remember to go Google you. But what I really want is to find out if I have talked with you in the past. So I want to right-click and search globally, search my e-mail and contact folders, search U.S. Search.com [which sells access to information stored in public records]. Who has that advantage? Microsoft is there, and for the low-price stuff that consumers aren't going to throw a whole lot of money at, they are in a terrific position."

MEANWHILE, BACK AT THE GOOGLEPLEX

I ask Google technology director Craig Silverstein whether Microsoft's search buildup keeps him up at night. He acknowledges that Microsoft and Google are exploring some of the same technical territory but contends that because Google is so much smaller than Microsoft (1,000 employees versus 55,000), it can act more nimbly on its ideas. And despite its smaller size overall, Google has more researchers devoted primarily to search than Microsoft. Silverstein also points out that each of Google's several hundred software developers is required—as part of the job—to spend 10 percent of his or her time on far-out personal projects, which provide a continuous flow of creative ideas.

Some of those projects surface at Google Labs (labs.google.com), a section of the Google site where the public can try out—and comment on—search-related software that's still in development. Google Viewer, for instance, animates results so that they scroll up the screen like movie credits. Voice Search lets you enter a search by telephone if you happen to be away from your desk, then retrieve the results online later. The Google Deskbar installs a permanent Google search box in the Windows taskbar; results appear in a small, temporary window, so users don't have to launch their Web browsers every time they want to look something up.

But none of the Google Labs prototypes represents an innovation of the magnitude of Page and Brin's original PageRank algorithm. Nor are they in the same league as Microsoft's effort to reinvent Windows and integrate the applications that run on it. While Silverstein and his colleagues will talk about the efficiency of Google's more than 10,000 Web servers and the passion and drive of Google's programmers, they won't say how the company hopes to improve PageRank, or what new technologies might counter threats such as Teoma and AskMSR. So in the end, there's little outward proof that Google has the new ideas it will need to retain its market share. Says open-source programmer Doug Cutting, "Google has a whole lot of people trying to come up with monumental advances, but we haven't seen them. I think if they had them, they would show them."

If there is one message spread by the priests of the dot-com boom that still holds true, it is that people's desire for faster, more efficient ways to do things trumps brand loyalty every time.

One thing Silverstein does like to talk about is his long-range goal for search technology, which he believes is still in its infancy. "It's clear that the answer [to search] is not a ranked list of Web sites," he says. No one expects to approach a librarian, ask a question about the Panama Canal, and get 50 book titles in response, he argues. Silverstein thinks information retrieval experts should aim high, building software that is every bit as good at pointing users toward the specific resources they need as a well-trained reference librarian. That, of course, will require major advances in fields such as probabilistic machine learning and natural-language processing—and Google continues to hire some of the best new PhDs in those areas, including four recent graduates from the Stanford laboratory of Daphne Koller, a leading machine-learning researcher *(see "10 Emerging Technologies That Will Change Your World,"* TR *February 2004)*.

But will all that talent be translated into tools people can use? Google itself appeared seemingly from nowhere, rapidly overshadowing other prominent search engines such as AltaVista. And if there is one message spread by the priests of the dot-com boom that still holds true, it is that people's desire for faster, more efficient ways to do things trumps brand loyalty every time. If rivals like Ask Jeeves and upstarts like Mooter or Dipsie achieve even part of their visions of better ranking algorithms, simpler interfaces, and larger, more comprehensive indexes, they could take a big bite out of Google's business. Microsoft's sweeping overhaul of the Windows environment, meanwhile, promises to change the very concept of search for the vast majority of computer users.

The good news for Internet surfers is that competition will make search utilities an even more helpful part of our daily lives. Without search tools, the Web's riches would be just as inaccessible as the tablets, scrolls, and hand-copied tomes of the pre-Gutenberg age, and as the Web itself grows, so does our need for better ways to penetrate it. But which technologies will provide the access we crave—and who will profit most from them—are questions that not even the best search engines can answer.

Wade Roush is a *TR* senior editor based in San Francisco.

By Chuck Lenatti Photographs by Angela Wyant

NANOTECH'S FIRST BLOCK-BUSTERS?

Having recruited some of the field's top scientists, Nanosys is intent on making real products that could transform the electronics and energy industries—and make nanotechnology commercially viable.

Show and tell: Nanosys cofounder Stephen Empedocles holds a sheet of transistors fabricated on flexible plastic.

IF YOU DRIVE EAST from Highway 280 on Page Mill Road in Palo Alto, CA, it's hard to miss Hewlett-Packard. The giant computer maker's stately headquarters sprawls along the right side of the street, overlooking a maze of parking lots. Harder to spot is Nanosys, a small nanotechnology startup tucked away in a low-slung bungalow across the road.

But Nanosys's humble facade masks the bubbling excitement of one of nanotech's hottest startups. Emerging from conference room Selenium—rooms here are named after elements in semiconductor materials—Stephen Empedocles, Nanosys's cofounder and director of business development, and Erik Scher, a Nanosys chemist, produce two small vials of what looks like snow cone syrup, one glowing blue and the other red. In the vials are "nanocrystals," tiny semiconductor particles. Since the crystals are too small to be seen by the naked eye, Scher switches on a computer that displays their magnified images; spheres, stars, and thin rods fill the screen. Nanosys is betting that these particles will be building blocks of the coming commercial revolution in nanotech.

Because the particles are engineered on the nanometer scale, Empedocles says, many of their fundamental properties—chemical, optical, electronic—can be precisely controlled. Nanosys researchers believe that by manipulating the crystals' composition, size, and shape, they can make a wide range of nano-based devices optimized to conduct electricity, sense chemical reactions, or convert energy from one form to another. Nanosys is beginning to use these resources to design novel products: supercheap solar cells that will show up in construction materials in the next few years; faster, lighter, and more efficient computer displays that could be commercially ready within five years; and nanoscale lasers, sensors, and computer chips that, farther down the road, could have widespread applications in electronics.

That's the promise, at least. And while dozens of other startups are also vying to emerge as the first successful company to develop nanodevices *(see "Other Startups in Nanoelectronics," p. 50)*, Nanosys appears to be in a particularly strong position. The company has signed on some of nanotech's leading academic researchers and has built up a body of scientific expertise reminiscent of powerhouses like Genentech in the early days of the biotech industry. And with more than $70 million in financial assets, including venture capital investments, corporate partnerships, and federal research grants; the rights to some 150 patents; and alliances with large manufacturers like Intel, Nanosys also seems to have the business resources to play a leading role in transforming nanotech into a viable industry.

"What Nanosys is doing is very important," says R. Stanley Williams, director of quantum science research at HP and an expert on nanoscale electronics. By targeting specific products, like solar cells and computer displays, the startup has focused its know-how on real markets. "They're taking this core expertise that's being developed around nanotechnology and finding an economic niche for it by inserting it into something that's already used or needed today," says Williams.

For the fledgling nanotech industry, however, the window of opportunity will not stay open indefinitely. After several years of hype over its potential, if nanotech fails to meet expectations to "get the first real products out in the next couple of years," says Empedocles, "the industry could be in trouble." And the clock is ticking for Nanosys in particular, since its financial backers are counting on a return on investment in another three to five years. While no one expects Nanosys to compete with the HPs and Intels of the world anytime soon, it does need to hit the market quickly to prove itself—and help dispel the notion that nanotech's potential is overblown.

WHILE DOZENS OF STARTUPS ARE VYING TO EMERGE AS THE FIRST SUCCESSFUL COMPANY TO DEVELOP NANODEVICES, NANOSYS COULD PLAY A DOMINANT ROLE IN TRANSFORMING NANOTECH INTO A VIABLE INDUSTRY.

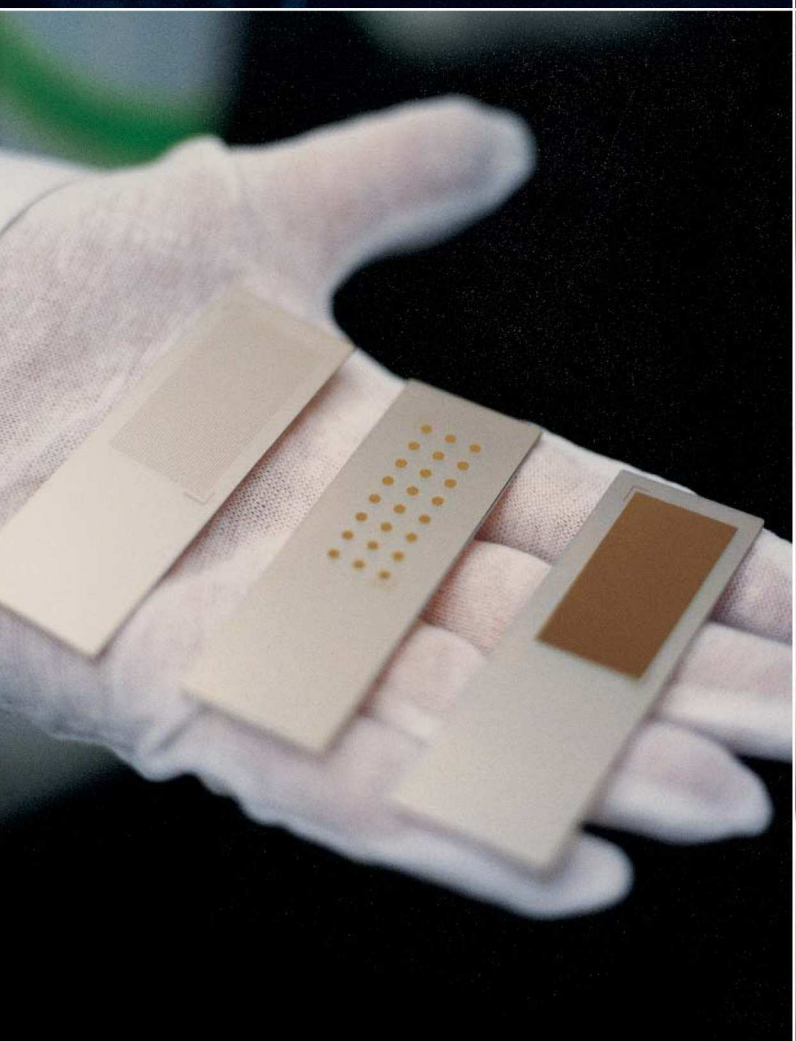
NANO SOLAR CELLS

The story of Nanosys begins with Larry Bock, a former biotech entrepreneur who is now the company's executive chairman. In the 1980s and '90s, Bock helped start 14 biotech companies, including Athena Neurosciences, which was acquired by Elan Pharmaceuticals for $700 million in 1996. But by the late 1990s, Bock had soured on opportunities for startups in biotech. "It used to be you could cut five deals with big pharma and go public," he says. "Then all of a sudden, there weren't even five big pharma companies around." Barely in his 40s, Bock went into retirement.

Browsing through the journal *Science* one day, Bock was astounded to see so many articles devoted to nanotechnology—"something I had never even heard of," he says. Intrigued, he spent a year meeting with nanotech experts to identify business opportunities. His conclusion: materials known as inorganic nanocrystals held great potential for near-term products. Unlike more exotic nanomaterials like carbon nanotubes, inorganic nanocrystals were made of silicon and other materials already familiar to electronics makers. Plus, in theory at least, the properties of nanocrystals could be easily manipulated to make useful devices. All of a sudden, Bock was out of retirement and back in the game.

By August 2001, Bock had founded Nanosys together with Empedocles, CEO Calvin Chow, and a handpicked team of top scientists from MIT, Harvard University, and the University of California, Berkeley. The game plan was simple but ambitious: turn this scientific expertise into real products for existing markets—and think big. First on the list: revolutionize energy technology.

One of the recruited scientists was UC Berkeley chemist Paul Alivisatos, who was already using nanotech to try to develop a cheap, renewable energy source. In his basement lab at Berkeley, Alivisatos was building new kinds of materials for solar cells, made of bar-shaped semiconductor rods just two to five nanometers wide and 60 to 100 nanometers long. In 2002, Alivisatos showed that by mixing these "nanorods" with an electrically conducting polymer, he could make a flexible material that behaved much like a traditional solar cell.



Nanomaterial sampler (clockwise from upper left): Weights stuck to glass with nano adhesive; nano solar cells on chips; flexible, high-performance electronics; supersensitive biochips.

Each nanorod absorbs sunlight and turns it into a highly efficient flow of electrons along its length. If the material is sandwiched between two electrodes—say, above and below—then any rods oriented vertically contribute to a usable electric current. And because the nanorods can be grown in one step and processed like plastic—without the high heat, vacuum ovens, or precise layering silicon wafers require—the material is five to ten times cheaper to make than a conventional solar cell.

But it is the overall energy efficiency of the material that really counts. To be a viable product, nano solar cells need to convert 10 to 15 percent of the solar energy they receive into usable electricity. They're not there yet, but possible solutions are in the works. Alivisatos found, for instance, that if he grew "nanotetrapods" shaped like a child's jacks instead of rods, the nanomaterial yielded a higher efficiency. It turns out that these new tetrapods are better at herding electrons, so they produce a greater electric current.

In a back room at Nanosys's Palo Alto labs, Erik Scher is attempting to turn these scientific discoveries into materials suitable for products. To concoct the nano solar cells, he uses a syringe to inject semiconductors into a heated, soapy solution of other chemicals. As the solution cools, the semiconductors crystallize into tiny nanostructures. Empedocles compares the process to making rock candy by supersaturating hot water with sugar—but on the nanoscale. The exact recipe determines the dimensions and solar-conversion properties of the crystals. Then another team of scientists measures how much light each type of crystal absorbs and how much electricity it produces. The result: a sheet of material coated with nanorods and optimized to convert sunlight into electricity.

Unlike conventional solar panels, which can be bulky and unsightly, Nanosys's finished product could be laminated onto regular roofing tiles or embedded in architectural glass *(see "Recharging Your Roof," p. 52)*. Wires connected to electrodes that sandwich the material would transmit electric current to a battery or back to the power grid. Spread over large surfaces, these solar cells could provide enough electricity to run home appliances, office equipment, and even buses. Working with Nanosys, Matsushita Electric in Osaka, Japan—a large maker of solar-integrated building materials—plans to put the solar cells into its roofing tiles within a few years.

This could change the future of energy, experts say. Although their market is growing, conventional solar cells have been mainly limited to high-end homes and niche applications like satellites, because they are so pricey to manufacture. For most Americans, solar energy is still five times more expensive than electricity from the power grid. But at one-tenth to one-fifth the cost of conventional solar cells, the Nanosys material could finally make solar power competitive with fossil fuels. "That's a remarkable claim," says John Benner, an expert on photovoltaics at the National Renewable Energy Laboratory in Golden, CO. "That changes the face of a lot of things."

OTHER STARTUPS IN NANOELECTRONICS

COMPANY	TECHNOLOGY
Kovio (Sunnyvale, CA)	Nanoparticle-based printable electronics for chips and displays
Nanomix (Emeryville, CA)	Nanotubes for sensors and displays
Nantero (Woburn, MA)	Nanotubes for fast, dense, low-power memory chips
ZettaCore (Denver, CO)	Molecular electronics for ultradense memory systems

DAPPER DISPLAYS

Nanosys is also hoping to spur big changes in another area: consumer electronics. Today's computer-display manufacturers are limited by two factors. First, manufacturing the high-grade "single crystal" silicon used to make fast chips and processors is expensive and requires high temperatures, and the end product is too brittle to be layered onto large surfaces. Second, while so-called amorphous silicon—typically used in transistors that control whether display pixels are on or off—is easily and cheaply fashioned into thin-film electronics, it has slow electron flow and chews up a lot of power. Nanosys believes it can use nanotech to give the display industry the best of both worlds.

Nanosys is betting that the answer lies in nanowires—inorganic semiconductor structures only a few nanometers in diameter but up to hundreds of micrometers long. Pioneered by Charles Lieber, a chemist at Harvard and a scientific cofounder of Nanosys, nanowires are fast and efficient at moving electrons about. They can be used to create thin-film electronics with the performance of single-crystal silicon. Because their manufacture doesn't require high temperatures, they can form high-performance electronics on plastic. And they're cheap to make—like amorphous silicon.

In a first step toward making products for displays, Nanosys is assembling silicon nanowires en masse, using refined versions of techniques developed at Harvard and Berkeley. To grow the nanowires, automated systems control a series of chemical reactions in a vacuum-sealed gas chamber, depositing a "forest" of nanowires onto a glass surface. They harvest the nanowires and lay them down on plastic or glass in a continuous sheet. The aligned nanostructures are then connected to form transistors, using what Empedocles says are the same techniques used to pattern amorphous-silicon transistors.

If it works, this process could transform displays by allowing high-performance electronics to be spread over large areas, such as laptop screens. The result: better pictures and less battery drain. Laptop screens employing such nanowires will be faster and up to three times as energy efficient, says Empedocles. Since they will be made mostly of plastic instead of glass, they will also be lighter and more durable. Nanosys also envisions nanowire-based displays for personal digital assistants and cell phones. Currently, these devices can't handle video, because the refresh rate of today's small liquid-crystal displays is too low. With nanowire transistors, however, the screens could refresh much more quickly.

Eventually, nanowires could enable displays with built-in processors and memory, which would replace separate processing modules and hard drives. It's a technical leap, one that will require making complex circuit patterns and data interfaces out of nanomaterials. But if it becomes feasible—and affordable—it could fundamentally change the devices that you use every day. "You can envision a substantial amount of logic on the display itself," says David Mitzi, an expert on device electronics at

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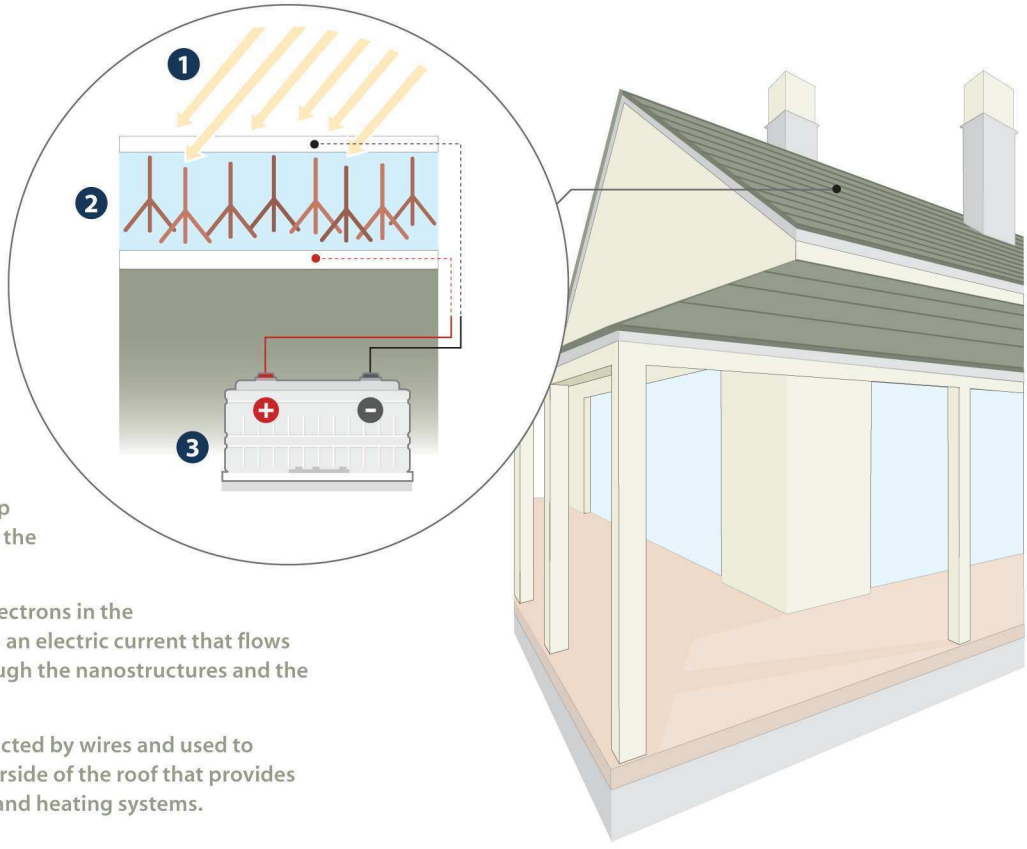

NANO SOLAR CELLS could soon turn sunlight into electrical power for your home. These supercheap solar cells—made of nanocrystal structures in an electrically conducting plastic, sandwiched between flexible electrodes—could be laminated in a thin coating onto ordinary roofing tile. Here's how it would work (drawing not to scale):

1. Sunlight penetrates the top electrode and is absorbed by the nanostructures (brown).

2. The solar energy excites electrons in the nanostructures, giving rise to an electric current that flows between the electrodes through the nanostructures and the polymer (blue).

3. The electric current is collected by wires and used to charge a battery on the underside of the roof that provides power for appliances, lights, and heating systems.

RECHARGING YOUR ROOF

IBM's Watson Research Center. "You might have an interactive display or even a whole computer on a plastic sheet."

VIALS TO VATS

Those are pretty heady ambitions. But for now, Nanosys is looking to be one of nanotech's survivors. And that means continuing to accumulate scientific expertise, efficiently scaling up its technology for the mass market, and keeping its focus on near-term revenues. While its solar-cell and display-electronics products won't be ready for a few years, Nanosys has already used its expertise with nanowires to develop a new kind of microarray, or biochip. The company is getting ready to market the chip for DNA and protein analysis in medical applications. The technology will allow researchers to use traditional detection methods, but it will provide up to ten times greater sensitivity than existing devices, in part because its arrays of nanowires have much more surface area for biomolecules to bind to. That could speed up drug discovery and make blood tests more precise—and establish Nanosys as a major player in the billion-dollar market for DNA chips.

The near-term strategy is that sales of these microarrays and other devices nearing completion, as well as revenues from industrial R&D partnerships, will tide Nanosys over as it scales up its production of devices for use in consumer products. The company has already outgrown its original headquarters and is expanding into adjoining buildings in its complex. It is also considering building a large-scale production facility off-site, and its industrial partners have signed on to help sell devices as diverse as solar cells, displays, radio frequency identification tags, light-emitting diodes, and antennas. The plan is that Nanosys will ship out sheets of nano solar cells, thin-film transistors, and other nano-based structures on plastic, and its partners will integrate these materials into products such as roofing tiles, architectural glass, computer displays, and electronic components.

If Nanosys gets that far—and it appears to be well on its way—it will need to grow its crystals in huge vats rather than tiny vials. In turn, transforming these vats of nanocrystals into complex devices like solar cells and thin-film transistors will represent a leap in manufacturing technology. It will also reflect nanotech's growing up and becoming a commercially viable way to make tomorrow's electronics. Focusing on how to use nanomaterials in devices such as solar cells may not be "as sexy as building nanocomputers," Empedocles admits. "But in terms of real market needs and real human needs, I think it's a huge opportunity."

So could Nanosys eventually become the next Intel or HP? No one will know for sure until it begins generating black ink on the bottom line—which could be only a couple of years from now. "Until you actually get products out there," cautions Larry Bock, "you'll never know whether the timing was right." One thing is clear: if Nanosys becomes a commercial success, it will be a sure sign that nanotech has come of age. TR

Chuck Lenatti is a business and technology writer based in Pacifica, CA.

+ISM (ROOF)

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Translation in the age of terror

The September 11 attacks **exposed the flaws** in the U.S. intelligence community's approach to translation. Now, the new federal **National Virtual Translation Center** seeks to dramatically increase the chances of **preventing the next attack** by using technology to leverage—rather than replace—**crucial human skills.**

BY MICHAEL ERARD

PHOTOGRAPHS BY JANA LEON

In a Washington, DC, conference room **soundproofed to thwart eavesdropping,** five linguists working for the government— **speaking on condition their names not be published—** describe the **monumental task** they face analyzing **foreign-language** intercepts in the age of **terror.**

Around the table are experts in Arabic, Russian, Chinese, and Italian, and a woman who is one of the government's few speakers of Dari, a language used in Afghanistan. They are young; three are in their 20s, the others in their 30s and 40s. But they are increasingly vital to U.S. national security: they are the front-line translators analyzing language that is messy, complicated, and fragmented but may give clues to an impending terrorist attack.

"Analyze" is the operative word here—not just "translate." Poring over documents and audio clips, the five—along with thousands of other government or contract linguists who do similar work—struggle to pull out single words, isolate fragments of information, weave intelligence out of the fragments, and generally perform linguistic triage on the flood of raw material collected daily by the CIA, FBI, Department of Defense, and other sources. One linguist tells of having to dig through a filthy box of documents, reeking of gasoline, that had just come off a plane from Afghanistan. Another describes decoding a handwritten note whose signature—a key clue to its intelligence value—was half ripped off. Another recounts listening to an intercepted cellphone conversation, in Russian, between two men in a noisy outdoor marketplace. One man was stuttering; that could have indicated he was nervous, which might or might not reflect the importance of the conversation. "It's like looking at the pieces of a jigsaw puzzle," without the box-top that shows what the picture is supposed to look like, says the Chinese linguist. "And maybe the pieces don't fit together. You have to brush off the dust and say, what do I do next?"

Beyond these physical and contextual stumbling blocks, analysts face challenges from the languages themselves. Al-Qaeda members tend to speak an Arabic saturated with cultural and historical allusions; that makes it tough to distinguish religious dialogue from attack plans. And some of the terror group's members aren't native speakers of the language, which means they make unusual word choices, pronounce words differently, and commit many grammatical errors. "We have a lot of practice dealing with the Soviet model or the European model of conversation," but not as much with cultures in which direct, plain language is rare, says Everette Jordan, a former National Security Agency linguist who arranged for the five linguists to meet with *Technology Review*. "It's not the where, what, how, and when. It's the why, and the why not. That's what we're encountering a lot."

The costs of failing to clarify what adversaries mean in a timely manner are high. That was made clear during Congressional investigations into the intelligence lapses that led up to the September 11 attacks. In perhaps the most glaring example, on Sept. 10, 2001, according to June 2002 news reports, the NSA intercepted two Arabic-language messages, one that said "Tomorrow is zero hour" and another that said "The match is about to begin." The sentences weren't translated until Sept. 12, 2001. The revelation underscored the fact that the U.S. government faces a serious crisis in its ability to store, analyze, search, and translate data in dozens of foreign languages.

It's a crisis that's getting worse—literally, by the hour. The backlog of unexamined material is so large, it's measured not in mere pages but in cubic meters. Consider that every three hours, NSA satellites sweep up enough information to fill the Library of Congress. And the NSA is only one intelligence agency. Somewhere in that massive haystack might be a needle about two kilobytes in size—the amount of data in a single typewritten page—in which terrorists let slip their plans.

And although there's a well-reported shortage of qualified translators to help search for that needle, there's a systemic problem, too. This deluge of intelligence is absorbed by a federal intelligence-gathering bureaucracy that is sprawling and balkanized. Four branches of the military, 13 intelligence agencies, and the State Department's diplomatic corps all have their own creaky systems built up over decades. Each agency houses—some say hoards—its own set of translators, analysts, and databases. Indeed, well before September 11, experts knew that the government's translation infrastructure wasn't only overwhelmed; it was obsolete. But the attacks provided the motivation to rethink, from the ground up, how translation gets done. "We're going through a cultural change right now," the Chinese linguist says. "We have to find the tools for the job."

A NEW THRUST

The locus of this cultural change—and shift in technology strategy—is several floors of an inconspicuous office building in downtown Washington, not far from the FBI's headquarters. This is the seat of the National Virtual Translation Center, a new federal office, created by the USA Patriot Act in 2001 but only funded in 2003. Its budget is secret, and last fall, most of its brand new cubicles stood empty. In one room, boxes that once held Dell computer monitors were stacked against a wall; in another room, Russian, Arabic, and Swahili dictionaries were still shrink-wrapped.

But the humdrum setting belies the center's pivotal role in transforming the U.S. government's approach to translation and analysis. It will act as the hub of a translation web serving all fed-

DC's Digital Dysfunction

IF THE NEW National Virtual Translation Center is to have any hope of resolving the U.S. government's translation crisis, it will first have to transcend a history of dysfunctional federal computer systems that may actually hamper analysts' ability to process foreign-language intelligence.

Two systems stand out as linguistic white elephants. One is a CIA information system—the **Corporate Information Retrieval and Storage** system—built in the 1990s to archive agency source documents. The system can't store or process any text that isn't in the Roman alphabet. The result? All words written with Arabic, Russian, or Chinese characters (to name just a few) have to be manually rewritten in the Roman alphabet before they can be stored.

Besides consuming huge amounts of time, this process—called transliteration—can cause information loss. For instance, the name "Suzuki," in Japanese characters, has 20 different spellings. But in the Roman alphabet, "Suzuki" has only a few spellings. The original distinctions in Japanese are largely lost to analysts searching the CIA database.

Making matters worse, until recently, federal agencies didn't even share the same rules for transliterating. There were six different sets of rules for writing Arabic in the Roman alphabet; thanks to this Byzantine system, the name of Libyan dictator Moammar Qaddafi can be transliterated 4,000 different ways. Although this glitch was recently resolved, the system still isn't truly multilingual, says Carl Hoffman, the CEO of Basis Technology, a Cambridge, MA-based multilingual-software company. In effect, he says, "the CIA has no technology structure for building a repository of foreign-language documents. That's a tremendous deficiency."

Meanwhile, a new $600 million FBI computer network called **Trilogy**—a system intended to bring multimedia case information from the FBI's massive databases of text documents, photos, and taped conversations to field agents' desktops—has its own limitations. Though the country's 13 intelligence agencies routinely deal with dozens of languages, the FBI system, like its CIA counterpart, cannot process all languages.

Trilogy has been partly implemented, but its final phase is late and tens of millions of dollars over budget. The FBI is now working on giving it the capability to process more non-European languages and non-Roman alphabets.

The National Virtual Translation Center hopes to deploy a new crop of more-focused technological-assistance tools. And that's a refreshing change from the traditional federal tendency to try and build huge central systems. "There's a pernicious view that there's a magic bullet for this," says William Rivers, the assistant research director of the Center for the Advanced Study of Language, a U.S. Department of Defense–funded research facility at the University of Maryland.

One advantage of the new center: it's run by former linguists who understand the everyday problems of the translation trade. With any luck, the center will succeed in bringing less glamorous but vital technologies to the analysts who so badly need them.

eral intelligence agencies. This year it's in the process of hiring perhaps 300 in-house linguists, but more significantly, over the next three to five years it will link tens of thousands of government linguists and private contractors via secure network connections of a type already used by the FBI and the CIA.

Its basic operating idea—break down bureaucratic walls and keep human translators at the center of the enterprise—stands in contrast to the government's traditional approach to the translation problem. Since the late 1940s, the U.S. government and its research agencies have spent huge sums trying to build the ultimate spy computer, which would automatically translate any sentence in any language, whether spoken or written, into graceful English. These efforts have provided some limited tools but haven't delivered on the larger vision. Computers simply aren't very effective at decoding language complexities that humans easily interpret.

The new translation center represents a major shift in the kinds of translation technologies that the government seeks to develop. In essence, the dream of universal machine translation is being pushed aside, in favor of a fresh thrust—one in which a variety of tools are developed, not to replace humans, but to assist them. "It's a model for how the government will deal with foreign language in the 21st century," says William Rivers, the assistant research director of the Center for the Advanced Study of Language at the University of Maryland.

For example, say Rivers and others, forget about software that can translate printed Arabic: analysts would benefit enormously if software could simply make Arabic writing easier to read, so that recovered documents could be more efficiently processed. "The government is appallingly behind on computer-assisted translation, because they've invested all this money on machine translation," says Kevin Hendzel, a former Russian linguist for the White House and now chief operating officer at Aset International Services, a translation agency in Arlington, VA.

For some old language hands, the new center is the realization of a long-held vision. "Ever since the 1970s, when the first PCs became available online, we've thought about how to link inexperienced translators to online dictionaries and expert assistance," says Glenn Nordin, a language intelligence official at the Department of Defense. "The [National Virtual Translation Center] is a dream of 20 years come true."

If it works, the center will tie together emerging translation-assistance technologies and deploy them efficiently on a massive scale. Administered from the DC offices, the translation web will also leverage the skills of people spread all over the U.S.: professors, contract translators, government linguists—greenhorn 20-somethings and retirees alike. "I can still reach the government [linguist] who has retired to Pocatello, Idaho, so we don't lose those skills out the door," says Jordan, who is the center's new director. "Right now, that's our only option."

TRANSLATION TOOLBOX

A suite of technologies—tools that can digitize, parse, and digest raw material for that translator in Pocatello—are at the heart of the center's efforts. From scanning software that recognizes more languages, to better databases that facilitate searches for translated phrases, to Web-based collaboration methods, the technological focus is on helping the linguist on the front lines.

The first step is simply to give the translator his or her work in digital form. "It's not only making the text machine-*readable*, but machine-*tractable*," says Jordan. "If you want to highlight something in the text and send it off to an offline dictionary or glossary, the machine really needs to be able to grab hold of the text and move it around." That requires digitizing printed documents so they can be handled by word-processing software.

Yet the enabling technology—optical character recognition software that recognizes printed characters and renders them in a standard digital font—leaves a lot to be desired. For one thing, it has been developed mainly for the Roman alphabet and the major European languages; for another, it follows language-specific rules and looks for distinct symbols—the letter *R*, for instance—whose boundaries and shape it has been programmed to recognize. While such technology exists for Arabic (and languages like Dari and Pashto, which are written in variations of the Arabic alphabet), it's reliable only on clearly printed—not smudged, blurry, or handwritten—documents.

This technological void slows the process of adding new languages to the scanning software, requiring a human expert to write out new rules. On the ground, it makes translators' work difficult from the start, often forcing them to do their work with pen and paper. "If the technology isn't up to date, it could be you and your dictionary," says the Italian translator.

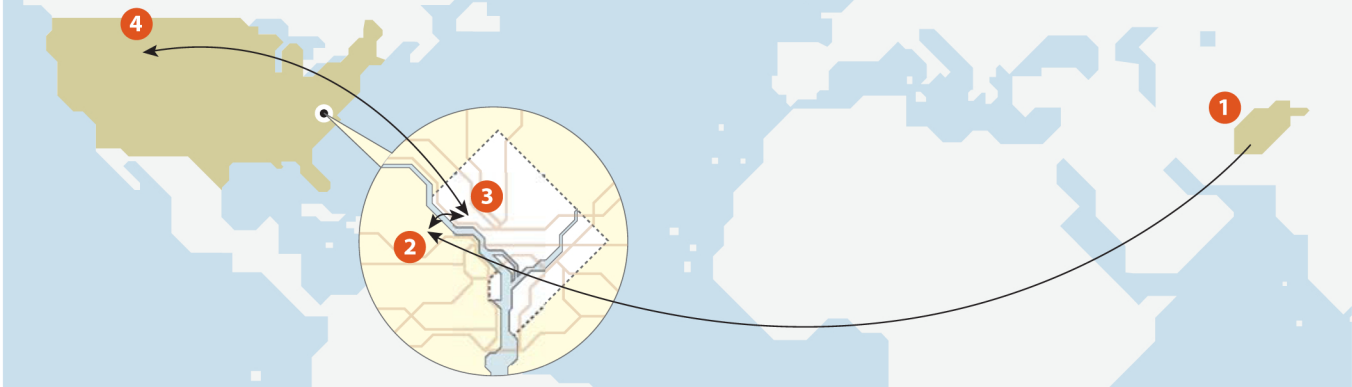
Improving the situation requires a new approach. A research group at BBN, a Verizon subsidiary based in Cambridge, MA, has developed a more flexible, trainable version of optical character recognition. For example, instead of just looking for an *R*, the system looks for a range of shapes that might be *R*s and hunts for possible matches in a list of models created during its training. This approach is more effective with blurry text and can be adapted to a wider range of languages, says Prem Natarajan, the technical lead on the project. Indeed, he says, the system has a high rate of accuracy with seven writing systems—Chinese, Japanese, Arabic, and Thai among them. The project already gets federal funding; its end product may be deployed by the new translation center.

With the BBN technology, documents in more languages could be scanned on the spot—say a cave in Afghanistan—and beamed directly to a translator. But getting the text in digital form is only the start. Another step in the virtual-translation center's technology assistance plan is to find and deploy software that can look for key words or phrases and flag suspicious documents for a closer look. These technologies can be applied to both digital text files and transcripts of voice intercepts.

It's not a new idea. But again, the existing software works mostly with European languages, for which private business markets have long provided the motivation for commercial development. The problem is that not all languages have structures and "words" that can be searched for in the same manner as those of, say, English or French. Arabic words, for instance, are generally written without vowels, and they include grammatical elements, such as markers for plurals, that make this rough translation process—often called "gisting"—more difficult. But one new gisting tool will help do rough terminology searches on materials in Arabic. It's called the Rosette Arabic Language Analyzer—developed by Basis Technology, a multilingual-software company based in Cambridge, MA—and it improves

A TRANSLATION WEB FOR NATIONAL SECURITY

The new National Virtual Translation Center aims to rapidly process foreign-language intelligence by forming a secure communications network and providing assistance technologies to human translators. In this hypothetical example, documents captured in Afghanistan are processed with the help of technologies from scanning software to shared databases of translated phrases.



1 U.S. operatives capture a box of waterlogged documents in Kabul, Afghanistan, and use next-generation scanning software to digitize them. The digitized documents are sent to the Defense Intelligence Agency at the Pentagon.

2 Faced with an overload, the Defense Intelligence Agency farms the job to the National Virtual Translation Center in Washington, DC. There, analysts use advanced software to flag important names and terms.

3 Most of the documents are free of ominous language, but one contains the word "fermenter." The center forwards this document to a retired Arabic translator with bioweapons expertise living in Idaho.

4 The Idaho translator does a partial translation using databases called translation memories that store common phrases. He determines that the document discusses pharmaceuticals and does not indicate a threat.

+ISM

searches by regularizing the spelling of Arabic words and removing confusing grammatical additions. The tool does the brute, repetitive work and lets humans spend more time actually analyzing the information.

After a document has been digitized and gisted, a linguist can grapple with it using another emerging assistance technology: translation memory. A translation memory works sort of like a spell-check application; it selects a chunk of text—whether a word fragment, several words, or whole sentences—and matches that chunk against previously translated material, saving time and improving accuracy by providing at least a partial translation. It's already a key tool in the medical and legal industries—where the same jargon frequently crops up in different languages.

The National Virtual Translation Center is **providing a model** for how the U.S. government will deal with **foreign languages** in the **21st** century.

Now, translation memory technology is being applied to intelligence work, which involves reading documents that are anything but formatted. Trados of Sunnyvale, CA—the biggest manufacturer of translation memory software—hopes to provide analysts with customized translation memories that work with summarized texts, not just full translations, says Mandy Pet, a Trados vice president. Last year Trados announced it was providing its translation memory software to the FBI's Language Division, which will be working closely with the new center.

Tying all these tools together will be an Internet-based system that will allow the new center to quickly dispatch projects to analysts in the field and will help those far-flung analysts more rapidly and accurately collaborate on the same projects. The precise, highly secure Web architecture that will allow this kind of collaboration is still under construction. Kathleen Egan, the translation center's technical director, says part of the challenge is to ensure that individual federal intelligence agencies keep their secrets—not only from hackers and terrorist infiltrators, but also from other federal agencies. This will require modifications of existing Internet collaboration software to allow sharing of some databases while protecting proprietary information.

FUTURE AGENDA

The most important question about the new translation center remains: will it have a noticeable impact on the nation's translation crisis? Some observers are skeptical. Robert David Steele, a former CIA officer who is now an intelligence community gadfly, puts it bluntly: "The FBI will fail because they lack the mindset to understand networks, translators without security clearances, and ad hoc contracting." He predicts the center will join other grand federal efforts that proved to have dubious value *(see "DC's Digital Dysfunction," p. 58)*. Meanwhile, other experts still see the future as lying in machine translation—and are working hard, often with government funding, to realize that vision. The new translation center "is the only way to go in the short run. But they may have to revisit that decision when technology overtakes it," says Jaime Carbonell, a computer scientist at Carnegie Mellon University and the chief scientific advisor for Meaningful Machines, a New York City startup developing machine translation products based on advanced statistical methods.

Whether or not automated computing tools overtake the more garden-variety helpers, though, the new center's role should be key. And its efforts could have a number of payoffs. The translation assistance technologies shepherded by the center could improve the U.S. government's ability to deal with information that's written in non-Roman alphabets, which will speed visa applications, passport checks at borders, and even tax returns. They could also make translation by corporations cheaper and faster. For example, better optical character recognition means cost savings for companies that read forms, such as bank checks or standardized tests. Large organizations like the World Bank and the United Nations have huge stockpiles of multilingual documents they want to digitize and put online.

What's already clear is that the very concept of the new translation center is driving innovation in the commercial sector. "We probably would not have done [the Arabic analyzer] if the government hadn't asked us to," says Carl Hoffman, the CEO of Basis Technology. "Once we've finished, we'll commercialize it and offer it to the private sector. There are customers for this kind of thing." For instance, he notes, if Basis Technology's Arabic analyzer were built into search engines, it would allow Arabic-speaking Internet users to match search terms that are not exactly alike. Google allows this kind of "fuzzy matching" in English. If you search the term "footbal," say, it will return a query asking if you meant "football." If this kind of benefit accrued to Arabic searchers, it would make the search engine a more powerful and global tool.

More broadly, the new translation center could prompt the creation of a variety of translation technologies for non-European languages. And the technologies that link translators might someday link students with teachers, potentially revolutionizing the way that languages are taught, says the government Italian expert. Somewhere down the road, the center even has the potential to spark the development of software in a host of less widely spoken languages, a boon to the globalization of computing *(see "Computers Learn New ABCs," TR September 2003)*.

For now, though, the National Virtual Translation Center is just trying to get up and running—and start helping linguists slog through messy, half-torn, ambiguous, and occasionally fuel-soaked intercepts. "If we don't understand a piece of information, then no one will know that it even exists," Jordan says. "It is our job to come into work every day and be prepared to do the first pass on the material. Either you're gisting, or you're translating, but it's all up to you." Nobody knows that better than the five linguists who met with *Technology Review* in Washington. They're waiting for help to better put the pieces together before the next zero hour arrives. No machine can do it alone.

Michael Erard writes frequently about language and technology. He lives in Austin, TX.

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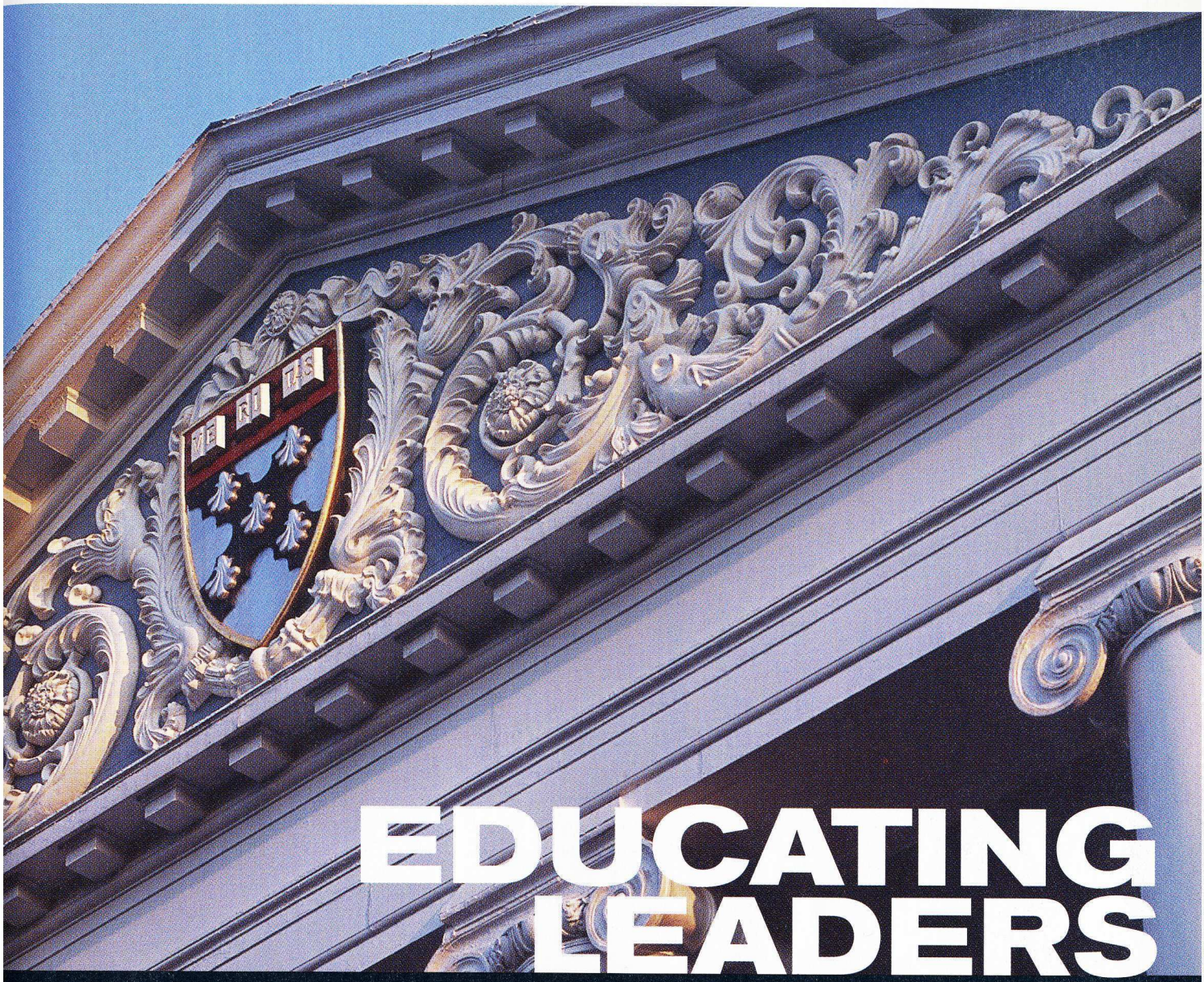

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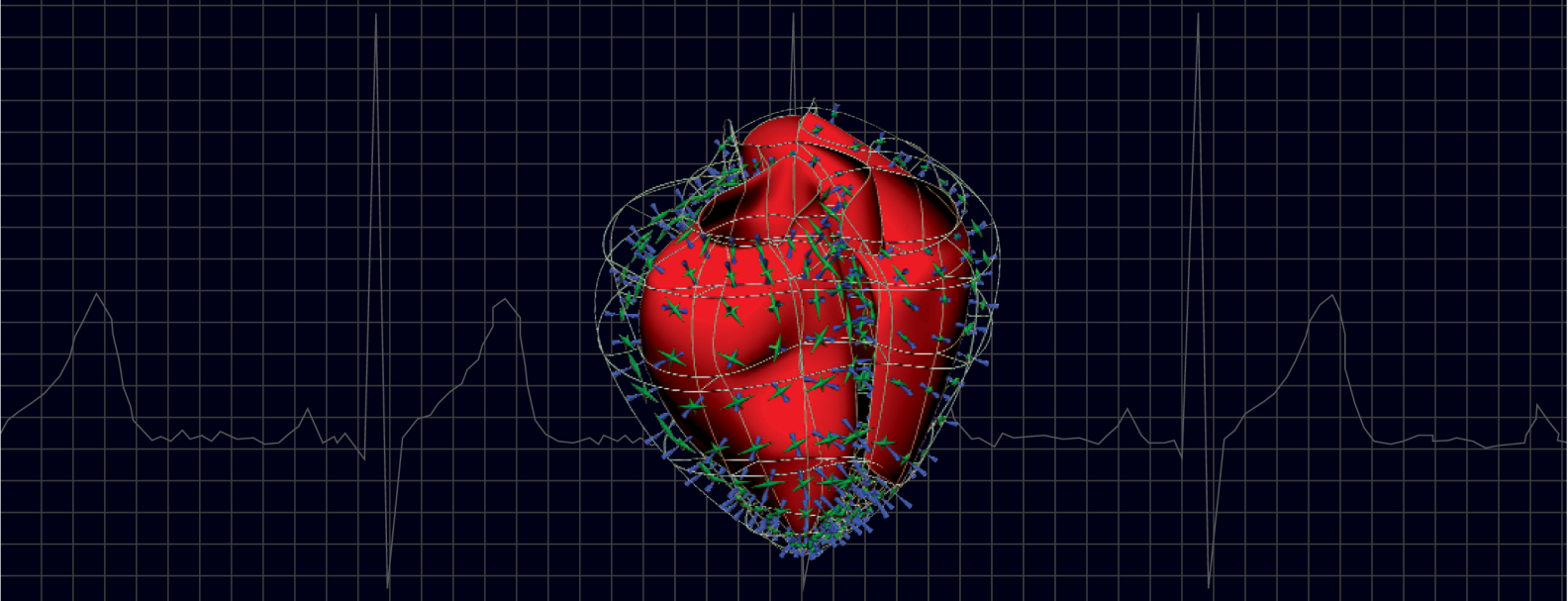
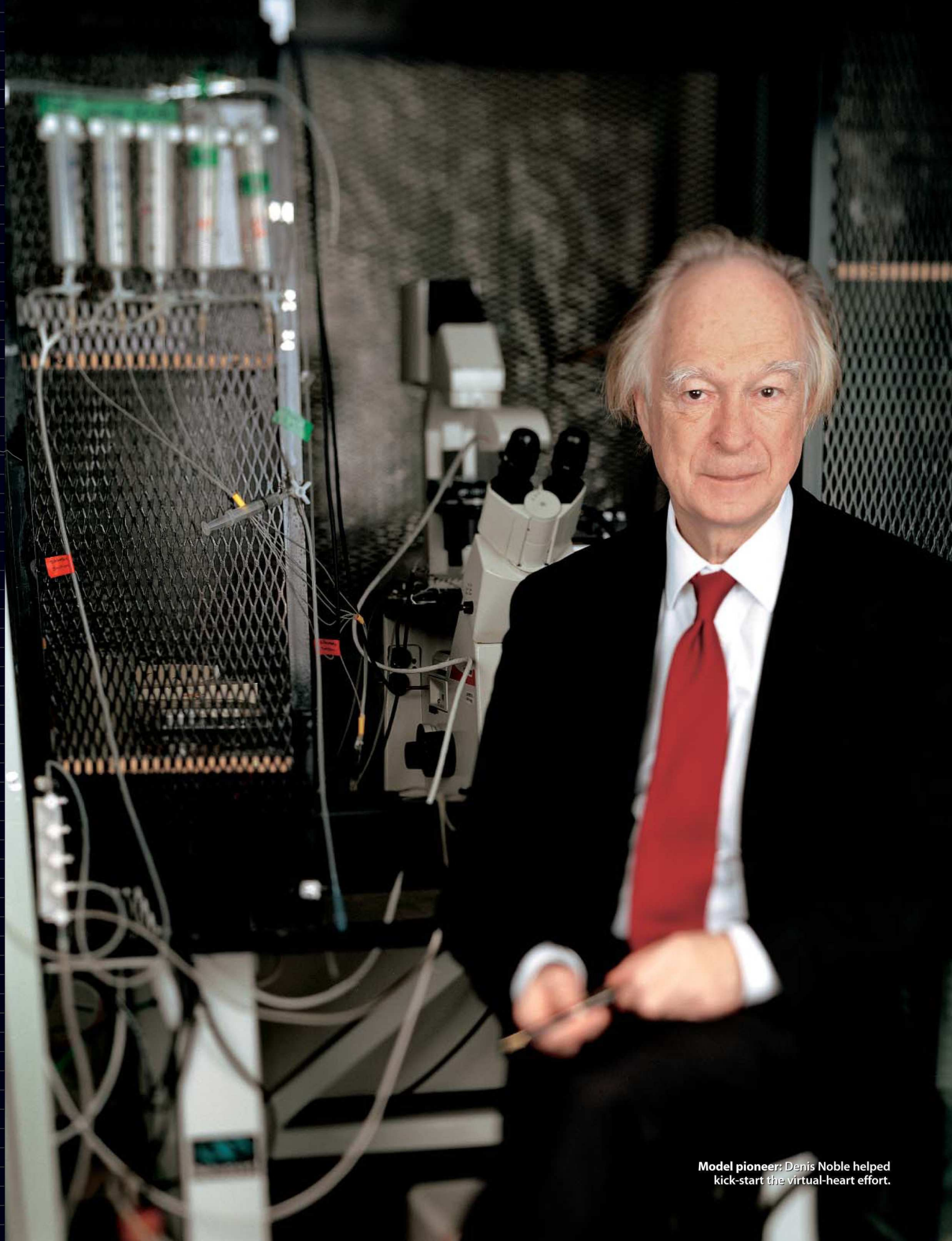


THE VIRTUAL HEART

A WORLDWIDE EFFORT TO BUILD A LIFELIKE COMPUTER MODEL OF THE HUMAN HEART COULD DRAMATICALLY IMPROVE THE DIAGNOSIS OF CARDIAC DISEASE, PROVIDE A MORE EFFICIENT WAY TO TEST HEART DRUGS, AND EVEN ALLOW SURGEONS TO TRY RISKY EXPERIMENTAL TECHNIQUES SAFELY. BUT SIMULATING THE MYSTERIES OF THE HEART ON A COMPUTER SCREEN ISN'T EASY.

BY DAVID H. FREEDMAN PHOTOGRAPH BY STEVE DOUBLE



Model pioneer: Denis Noble helped kick-start the virtual-heart effort.

THE 70-YEAR-OLD patient in the Auckland Hospital in New Zealand had suspiciously low blood pressure. The doctors were stumped. But they had an unusual experimental tool at their disposal: a unique computer program that analyzes a magnetic-resonance imaging (MRI) scan, measuring the motion of a patient's heart and comparing it to that of a "healthy" virtual heart constructed not of blood and tissue but from mathematical equations. The analysis handed the clinic's experts the smoking gun: part of the heart was twisting in a pattern often associated with a partially blocked valve, which, untreated, would probably kill the patient within three years.

To diagnose this disorder, surgeons would normally have to crack open the patient's chest. But the software had accurately identified the problem in about 15 minutes. "It helps point out where the heart wall may be failing," says Peter Hunter, the University of Auckland bioengineer whose team developed the software in collaboration with the German company Siemens.

The MRI analysis program is just one of a rapidly growing number of medical applications emerging from an ambitious global effort known as the cardiome project. The goal of this multilab endeavor is to build a virtual heart: a computer model that accurately depicts everything from a single cardiac cell up to the whole organ, from the interwoven electrochemical activities of millions of cells to the delicately synchronized pumping of blood. The model should even be able to "suffer" from the blocked arteries, weakened muscles, and erratic electrical rhythms that characterize heart diseases.

Medical researchers have been working on computer models of the heart for decades. But thanks to exponential leaps in available computer power, rapid progress in describing the precise and complex details of how the heart actually works, and the fashioning of mathematical representations of those details, increasingly lifelike models of the heart are beginning to yield real health dividends. Insights gleaned from the virtual-heart project are leading to new approaches to diagnosis, surgery, and drug discovery, with the potential to improve or even save the lives of the more than 13 million people in the United States alone who suffer ailments ranging from heart attacks caused by clogged coronary arteries to potentially fatal abnormal heartbeats triggered by rare genetic mutations. "We can do a good job now of modeling on a computer what happens to cardiac cells in heart failure, and predicting how a heart contraction will respond to a drug or other stimulus," says Andrew McCulloch of the University of California, San Diego, a leading researcher in the field. "It's allowing us to answer a lot of experimental and clinical questions."

The virtual heart is a work in progress that does not yet mimic many of the intricate and still mysterious genetic, cellular, and mechanical processes that take place in real hearts. Nevertheless, as the project's computer models improve over the next several years, they could revolutionize the diagnosis and treatment of heart disease by casting new light on the complex workings of the organ, and serving as tools for quickly and cheaply testing drugs, diagnostic devices, and surgical treatments that are still too risky to try on humans.

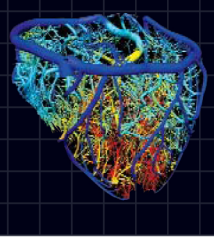
IN A HEARTBEAT

Though the virtual-heart project is of global scope and has no official headquarters, it is widely agreed that its front line lies beyond the University of Oxford's ancient, stately colleges, in a drab, modern building that looks out of place among its crenellated neighbors. Here, in a four-floor wing dedicated to cardiac science, is a research center equally uncharacteristic of its surroundings. Instead of stainless-steel tables, microscopes, and flasks of cells, this modest suite of offices is packed with computer workstations whose monitors are filled with strings of software code. This is the domain of Denis Noble, a man credited with almost single-handedly creating the field of cardiac modeling nearly 45 years ago. These days Noble, head of Oxford's Cardiac Electrophysiology Group, is easy to spot among the graduate students and postdocs: a lean 67, he is the most hiply dressed and also appears to hold a solid edge in energy as he dashes among team members whose work ranges from hard-core computer programming to basic tissue dissection. Cardiac modeling, Noble says, necessarily combines the talents of researchers who might never otherwise come in contact. "This is a new form of biological science," he says. "Being highly collaborative is essential."

In a sense, the cardiome project began in 1960 when Noble came up with a set of equations that describe how the electrical activity of cardiac cells is largely controlled by the flow of potassium ions through their membranes, which leads to waves of activity that spread through neighboring cells and ultimately generate the coordinated beating of the heart. While the idea of describing physiological activity in terms of mathematical equations seemed groundbreaking at the time, Noble's original model appears almost quaint compared to those his lab works with now—monstrous formulas with 23 variables accounting for 12 different types of cellular ion flows. Crunched on a computer, these models churn out a millisecond-by-millisecond simulation of a cardiac cell's activity.

But modeling a single heart cell gets you only so far. Helping patients diagnosed with diseases from high blood pressure to congestive heart failure requires a model of the entire organ.

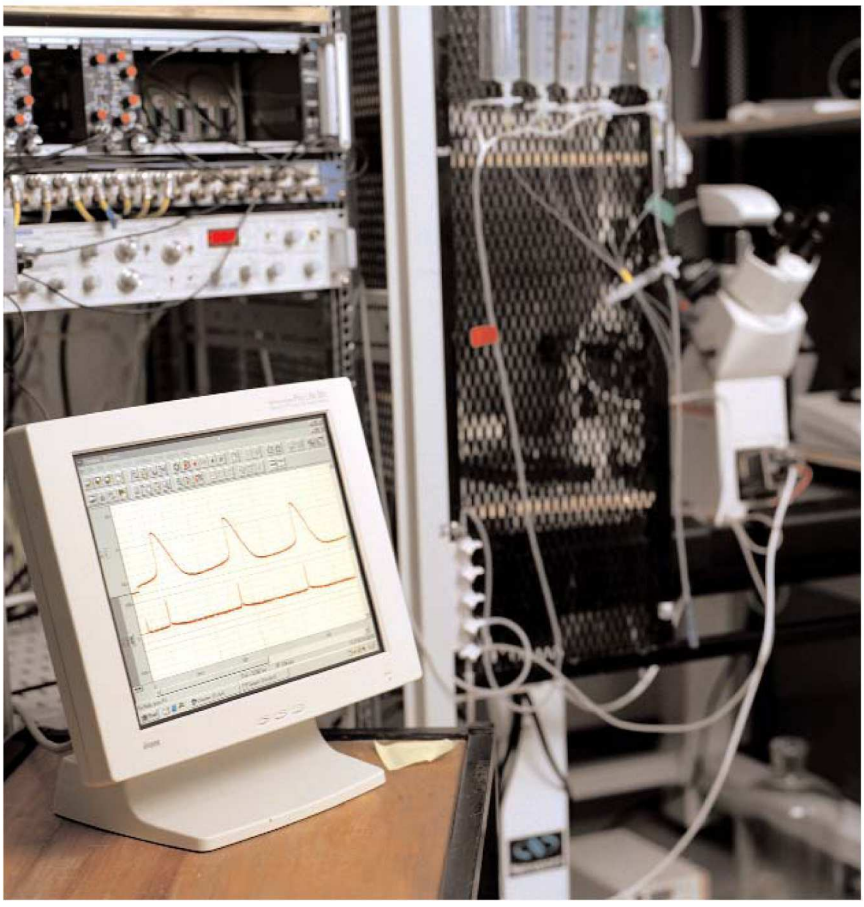
PHOTOGRAPH: LANCE CLAYTON; ILLUSTRATIONS: NIC SMITH (BLOOD VESSELS) AND RICHARD CHRISTIE (HEART MODEL, PREVIOUS SPREAD), BOTH OF THE AUCKLAND BIOENGINEERING INSTITUTE



COMPUTER MODELS OF THE HEART, SAYS BIOENGINEER PETER HUNTER, CAN POINT OUT ASPECTS OF DISEASE SUCH AS **WHERE THE HEART WALL MAY BE FAILING**—ALLOWING DOCTORS TO CHOOSE THE BEST TREATMENTS FOR THEIR PATIENTS.

« MODEL OF THE BLOOD VESSELS THAT FEED THE HEART.

Virtual vision: Chris Johnson sports special glasses that reveal his heart models in 3-D.



Cellular close-up: Researchers use specialized equipment to collect data on the electrical activity of cardiac cells and feed it into heart models.

Enter Peter Hunter, a former Oxford colleague of Noble's. Where Noble works on individual cells, Hunter has taken on the task of modeling the heart's large-scale structure and mechanics—that is, the beating of the heart muscle itself. When Noble visited Auckland in 1991, he found Hunter's group making ultraprecise measurements of hearts extracted from dogs. "These people were shaving down a preserved heart a fraction of a millimeter at a time, like old-fashioned anatomists," recalls Noble. Hunter's intent was to build a model that would bridge the gap between heart science at the cellular level and the structure and function of the whole organ. In other words, he wanted to map out exactly how all those ion flows in cardiac cells teamed up to create a heartbeat, and in particular where things were going wrong in diseased hearts.

Today, the efforts of Hunter's and Noble's labs have been combined into whole-heart models whose behavior reflects the independently calculated activities of up to 12 million virtual cardiac cells. A real heart has closer to a billion cells, but even today's fastest supercomputers can't track that many cells in a reasonable amount of time. As it is, some of the Auckland models—which represent human, dog, pig, guinea pig, and mouse hearts—are so complex that it takes eight hours or more of a supercomputer's time to crank through a single heartbeat. Explains Hunter, "The models show how electrical activity originates at the cellular level, how the activation wave spreads to other cells, how the electrical wave is converted to mechanical contraction of the heart wall, how the contracting walls cause blood to flow through the heart, and how energy is distributed through the whole system."

Despite the complexity of these models, there was still a missing element: genes. It turns out that genes play an enormous role in heart disease; the inheritance of a single unlucky gene can raise the chances of early death from a long shot to a near certainty. Even genes that normally don't cause heart problems can do so when they are switched on or off or damaged by environmental influences, such as cigarette smoke or stress. To make things even more complicated, heart disease itself can influence cardiac genes in ways that accelerate the disorder or cause new complications. To accurately model disease in a heart, researchers must account for these genetic factors.

Working with UC San Diego colleagues, McCulloch is using genetically engineered mice to identify genes that play a role in heart disease. He is then using that information to modify virtual-heart models. McCulloch's lab uses mice with changes in a single gene that render it either constantly active or constantly inactive. These altered mice are then studied for differences in cardiac functioning and susceptibility to heart disease; any such differences can generally be attributed to the altered gene. If a mouse that has had a certain gene made continually active develops heart disease at an unusually early age, for example, then the computer model can be adjusted so that switching that gene on in the virtual heart will trigger disease processes. Such modifications can be critical in making the models more realistic. If the virtual heart is used to investigate a drug designed to prevent the onset of heart failure after a heart attack, for instance, then it has a better chance of predicting how well the drug will work if it includes the genetic processes that the drug might influence.

Built up from the workings of individual cells and genes, the virtual heart presents a vivid image of the vital organ. But is it a realistic one? The models provide what are essentially predictions of how a real heart would behave, and researchers need ways to ensure the accuracy of these predictions. Chris Johnson, a computer scientist who directs the Scientific and Computing Imaging Institute at the University of Utah in Salt Lake City, has created one solution: a way to gauge the models against data from living volunteers.

The main tool for measuring the heart's electrical activity, an electrocardiogram that takes readings from 12 electrical leads, yields only a relatively crude analysis. But a "jacket" developed at the Cardiovascular Research and Training Institute at Utah that employs 192 leads, along with a standard MRI scan, gives Johnson a much more complete picture. To translate the jacket's measurements and the MRI data into a detailed picture of the heart's electrical activity, Johnson first takes into consideration how bone, blood, fat, and muscle distort a signal traveling from a particular point on the heart to a particular point on the skin. He can then infer an electrical map of the heart at any point in time. "We're taking voltages from the outside and determining what they

STEVE DOUBLE

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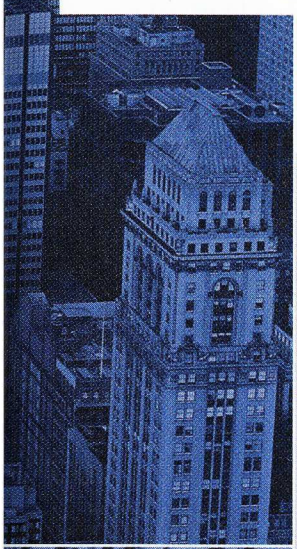

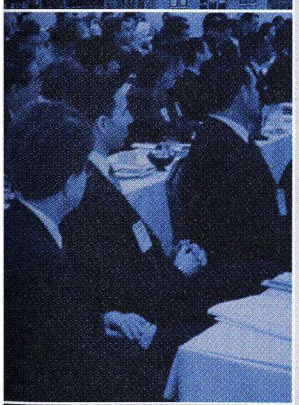

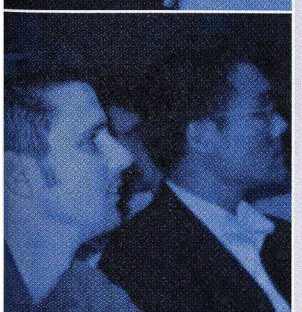

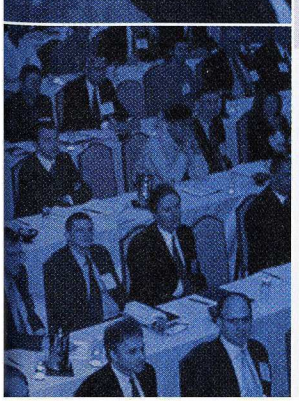

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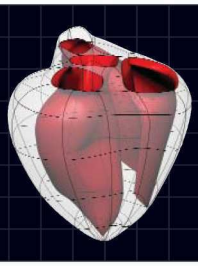

THE VIRTUAL HEART HAS, IN MANY WAYS, COME ALIVE IN THE LAST DECADE. **"WE CAN MODEL A HEARTBEAT OVER A PERIOD OF 10 MINUTES,"** SAYS BIOENGINEER ANDREW MCCULLOCH. "BUT WE CAN'T YET MODEL THE PROGRESSION OF DISEASE."

« MODEL OF THE PUMPING OF A PIG'S HEART.

would be on the surface of the heart," he says. This allows the modelers to determine whether their millisecond-by-millisecond predictions of the heart's electrical activity are accurate—and to fine-tune their calculations to bring them closer to reality.

Johnson's models and the electrode jacket are also in experimental use to help cardiologists spot heart disease. While electrocardiograms of hearts with potentially fatal artery blockages often look completely normal to all but the most expert eyes, the jacket-based system generates almost MRI-like images that can reveal blockages and other defects with such stark clarity that even a layperson can spot them. Johnson's team has also created software that allows the simulations to be viewed in 3-D with special stereoscopic glasses. The improved view could, for example, allow doctors to initiate drug therapy or perform artery-clearing angioplasty earlier than they might otherwise, which could help prevent heart attacks or avoid the need for more invasive coronary bypass surgery.

VIRTUAL YOU

The virtual heart has, in many ways, come alive over the last dozen years. But it still has a long way to go. "We can model a heartbeat over a period of 10 minutes," says McCulloch. "But we can't yet model the natural progression of disease—how a cardiac cell gradually proceeds from normal to injured to failed." One barrier: although hundreds of researchers around the world are exhaustively deciphering the workings of the heart, most biologists haven't been trained to gather and present data in a rigorous, quantitative way that can feed into the mathematical formulas used to build computer models. "When you talk to them about describing their results as formulas, some of them get very turned off," says Paul Herrling, head of corporate research for pharmaceutical maker Novartis.

Yet the cardiome is already making contributions to medicine, and one of its biggest may be as a tool to help researchers discover better heart drugs. Novartis, for one, is already using cardiome models to develop drugs by programming in the changes that a compound has been observed to make in a cardiac cell, and then letting the model project how those changes will affect heart rhythm and blood flow. "We've been able to make predictions of which ion channels in heart cells to tweak with drugs to reduce arrhythmias," such as those found in patients who have suffered heart attacks, says Herrling. He emphasizes that the cardiome needs a great deal of additional development before it's capable of providing detailed, complete, accurate predictions of how the heart would respond to a wide range of potential drugs. "But we've had a sufficient number of elements come together to allow getting a good start," he says. "That tells me it's worthwhile pursuing the models, even if they're not perfect yet."

The virtual hearts are also advancing surgical therapies. For example, about five million Americans suffer from congestive heart failure, and one relatively new treatment that is gaining popularity involves implanting two pacemakers in patients to counter the abnormal heart rhythms typical of the disease. But doctors can have trouble determining the sequence of electrical stimulation that best ensures a stronger heartbeat. So McCulloch has adapted one of his models to simulate a diseased heart with two pacemakers, allowing him to experiment on a computer to find the right placement and timing for the two jolts. "There's intense interest in the work from pacemaker companies," he says.

As exciting as these early applications are, the modelers have far greater ambitions. Eventually, biologists and physicians hope, modeling research will give life to an entire virtual patient, with a full complement of simulated organs. That would enable, for example, studying how an experimental heart drug affects the kidneys, or identifying the long-term effects of a high-fat diet within weeks, rather than following human volunteers for years. Taking one small step toward this lofty goal, Hunter is helping to oversee the development of an open-standard programming language called CellML, based on XML, the Web page development language. Over the next two or three decades, CellML and other such standardized tools will give modelers the world over a common language and enable the integration of the cardiome work with computational models of other organs. "We're all asking ourselves what sort of infrastructure we need to make sure our work is expandable and extensible to other applications at other levels," says Johnson. "We don't want the cardiome to be a one-off."

The flurry of modeling is leading to a promising trade-off: the better we get at creating virtual heart disease, the less we stand to see of the real variety. TR

VIRTUAL HEARTS IN OPERATION

COMPANY	APPLICATION
Artesian Therapeutics (Gaithersburg, MD)	Cardiac models to support drug development
Immersion Medical (Gaithersburg, MD)	Whole-heart models for training surgeons
Insilicomed (La Jolla, CA)	Whole-heart models for medical-device design
Predix Pharmaceuticals (Woburn, MA)	Cardiac cell and tissue models for drug discovery

David H. Freedman is a freelance journalist based in the Boston area and the author of five books. His last article for the magazine was "Gadgets in the Superchip Age" (February 2004).

CAREY STEVENS, THE AUCKLAND BIOENGINEERING INSTITUTE (HEART)

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HOLLYWOOD'S MASTER OF LIGHT

PAUL DEBEVEC IS MIXING REAL-WORLD LIGHTING WITH CUTTING-EDGE COMPUTER GRAPHICS TO CREATE SOME OF THE MOVIE INDUSTRY'S MOST STRIKING—AND REALISTIC—EFFECTS.

PHOTOGRAPHS BY JOE TORENO

A SUNNY BEACH. A candlelit restaurant. A creepy dungeon. In the world of moviemaking, directors increasingly use digital tools to add real and virtual characters to different kinds of backgrounds. The key to making it look realistic? Lighting. "How actors are lit is a big deal," says Paul Debevec, a computer scientist who heads the Graphics Laboratory at the University of Southern California's Institute for Creative Technologies. By creating more accurate artificial lighting on a computer, he says, his team is "giving filmmakers more flexibility" in their shots and more efficient ways to generate effects. Which means time and money saved on shooting, editing, and drawing graphics—not to mention more convincing results. An eventual goal is to create more realistic digital characters and objects that can be used in any scene. But techniques based on Debevec's work have already been used by special-effects companies in numerous feature films, including the *Matrix* and *X-Men* series. At his lab in Marina del Rey, CA, Debevec showed *TR* associate editor Gregory T. Huang how to use light from the real world—and algorithms from the digital one—to render an actor's face as it would appear under any conditions, anytime.

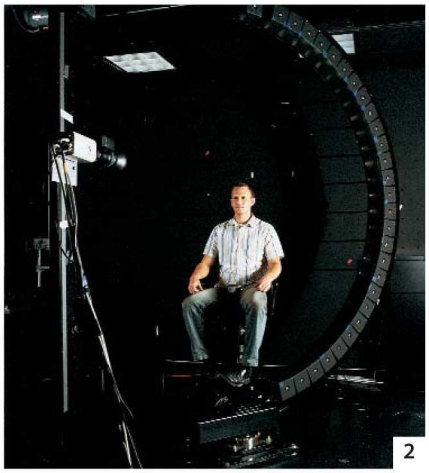
Brightest bulb: Paul Debevec is enlightening the world of digital special effects.

1

1. SUNSET SPHERE. Say you want to illuminate an actor in a studio as if he or she were on a rooftop at sunset. The first step is to capture light from the real world. On the rooftop of the lab, Debevec and research programmer Andrew Gardner set up a mirrored sphere on a tripod. Debevec takes photos of the sphere from different vantage points, using a specially calibrated digital camera. Light bounces off the sphere from many directions and into the camera lens, providing a 360-degree representation of the ambient light.

"By using a range of shutter speeds and exposures," says Debevec, "we record the full dynamic range of the light that's out here." So when it comes time to insert the actor digitally into the appropriate background scene, there's enough information captured—direct sunlight, diffuse light from the sky, reflections from the roof—to illuminate him or her very realistically. The light measurements recorded here are stored and will serve as a reference for artificial lighting conditions to be created on a computer.

2 – 4. LIGHTS, CAMERA, ACTION. Next up: photographing an actor so he or she can be digitally inserted into a scene, like the rooftop, with the proper illumination. Playing the role of an actor, Gardner sits in a chair next to a contraption called a "Light Stage": a three-meter-tall curved arm containing 30 strobe-light elements (2). Inside each strobe element is a transistor that switches it on and off in a millisecond and a programmable chip that listens for command signals from a nearby computer. A high-speed still



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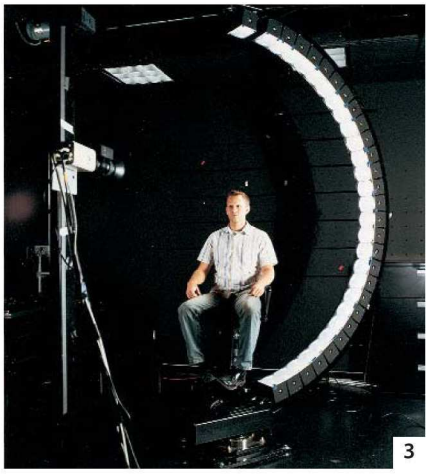

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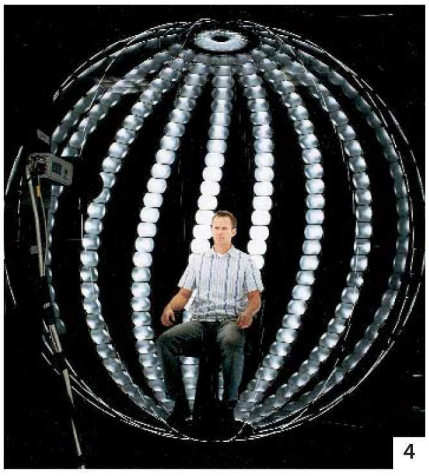

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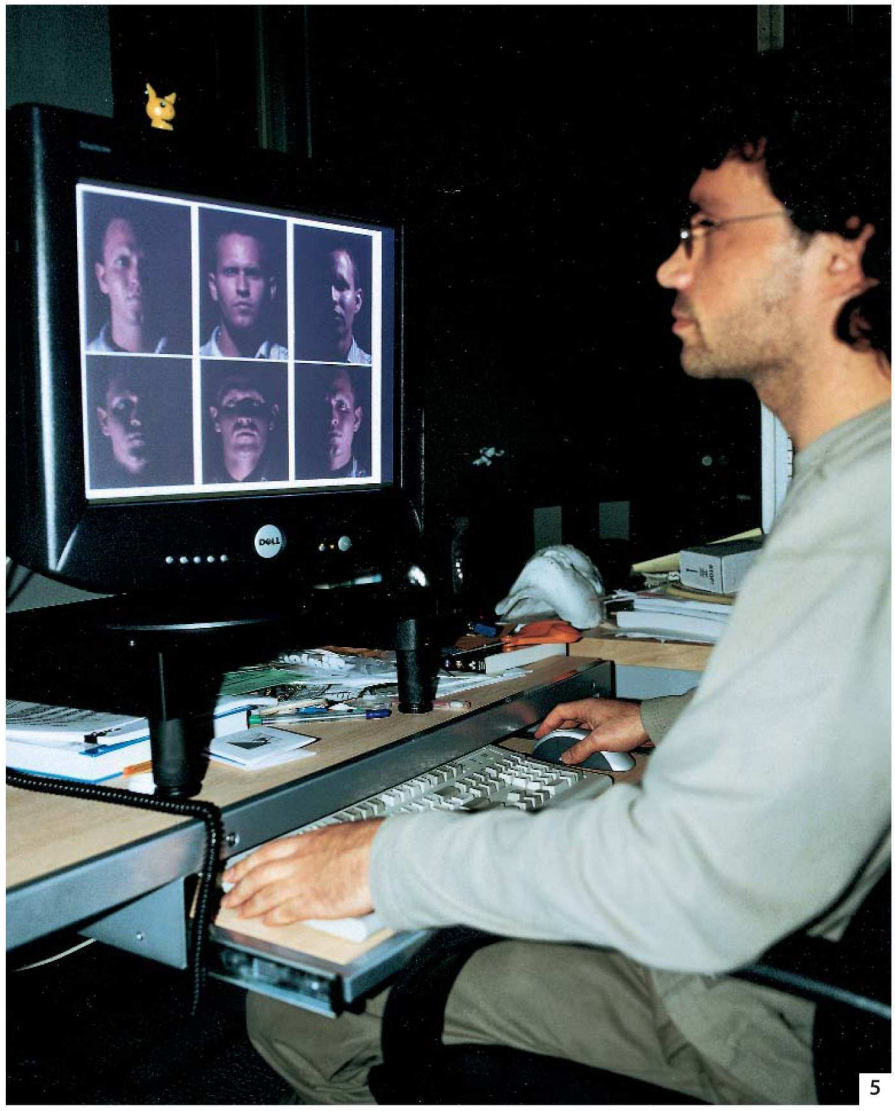
camera (foreground) takes snapshots of Gardner's face as the white lights pop off one at a time, synchronized to the camera's exposures (3). Then, to capture images of his face "lit from every possible direction," says Debevec, the Light Stage rotates smoothly in a circle around him for about 20 seconds (4). During this time, the stationary camera snaps hundreds of still images of Gardner, while the movements of the apparatus are controlled by the computer via an electric motor anchored to the ceiling.



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6

5. DIGITAL LINEUP. Now it's up to another research programmer, Tim Hawkins, to make sense of the data and put it all together in the computer. Hawkins's software sorts through the individual studio shots (six are shown on the screen) and can combine them in different ways to calculate how the face would appear "under any captured lighting," Debevec says. To recreate the sunset lighting, the computer superimposes the face images that correspond to the directions and intensities of the actual light captured on the roof.

6. FACE VALUE. The end product is a photo of Gardner illuminated digitally by the rooftop sunset (right). Compare that to the same face as it would appear in a courtyard in Florence, Italy, on an overcast morning (left). These images can now be placed into background scenes so that they match the lighting in those scenes—without the actor's ever having been there. So a movie director can put more realistic digital faces on extras and stuntmen and "punch in new lighting" if there are editing changes, say, that require a character to be somewhere else at a certain time of day, says Debevec. "We make it look real. Then the director can make it look right," he adds.

So far, these techniques apply to still faces and objects. A next step is to bring the faces alive by blending sequences of different expressions over time—say, moving the lips—which will give filmmakers another tool with which to paint more vivid and realistic motion pictures.

Domain Master

BY MARK FRAUENFELDER | Photograph by Tom Holland

PAUL TWOMEY
POSITION: President and CEO, Internet Corporation for Assigned Names and Numbers (ICANN)

ISSUE: Who will control the Internet? While no one owns the Internet, it can't function without ICANN, the U.S.-based nonprofit that manages the Internet's addressing system. ICANN is under fire from international organizations that say the United States holds too much control over the Net's core functions.

PERSONAL POINT OF IMPACT: Taking steps to further internationalize ICANN without handing over control to the United Nations

TECHNOLOGY REVIEW: What is ICANN, and what does it actually do?
PAUL TWOMEY: ICANN is a not-for-profit international entity. It's a public-private partnership that has representation from the technical community, the business community, governments, and representatives from the users of the Internet. It is tasked to help manage the coordination of the Internet's system of unique identifiers—in particular, Internet domain names, IP address numbers, protocol parameters, and port numbers—which are essential for the Internet to function. It also helps coordinate the stable operation of the Internet's root server system.

TR: That seems like pretty dry stuff. Why is the international community so unhappy, or at least concerned, about ICANN?
TWOMEY: At the WSIS [the United Nations' World Summit on the Information Society, held in Geneva in December 2003], a number of developing countries raised issues around so-called Internet governance. Because this is an area where it is quite unclear what anybody actually means, there was some confusion. Some people were talking about spam, child pornography, Internet taxation, and other issues like that.

We became conscious that in all the discussion around so-called Internet governance, there were actually four layers: a technical-coordination layer, a legal and jurisdiction layer, an economic- and development-issues layer, and a social and cultural layer. Because ICANN exists as the technical-coordination layer, I think we became a lightning rod for some discontent. Undoubtedly, part of the reaction of some of the developing countries is an anti-American sentiment and a broader desire to wrest the levers of international economic power from the North. The irony is that ICANN has been established to internationalize and privatize the functions that were previously being performed by the U.S. government in the original founding of the Internet. I think ICANN is more an instrument to achieve the objectives that people said they wanted as opposed to being some sort of barrier to them. But these things sometimes get caught up in emotions. They don't have that much to do with detailed facts and more to do with politics.

TR: But you're being embroiled in politics whether you want to or not.
TWOMEY: Whether we want to or not. My background is working in the nongovernment sector and also senior positions in two Australian government agencies. I understand the political environment and what drives it. We have been dragged into it. But my key point keeps coming down to how much we've got to educate people and get them to understand, and [also] hear their needs. We have to keep changing the quite natural center of gravity of thinking of the Internet, which was North America, where the Internet spawns from, to get it more and more in a global perspective.

If governments want to get together and talk about a lot of other issues, we have no view one way or the other. [But] at the technical-coordination layer, this system has been established for 35 years. It is an open, transparent, bottom-up system where the people who are involved in making the Internet work are the ones who make the decisions. It's not broken; don't try to fix it.

TR: After you flew 20 hours to attend the World Summit on the Information Society, guards ejected you from the opening meeting. What happened?
TWOMEY: What happened was the [delegates] said they were going to have open meetings, which meant that groups like ICANN could observe, [but] we couldn't say anything. But at the last minute the chair decided to make the whole thing closed. It wasn't just myself, but others who were not members, who were all escorted out. The bottom line is that's the way they hold their meetings: in private. They're secret. That's the way the governmental organizations work. We are an open, transparent organization. Anything that has to be discussed has to be put up on the Web site. Anybody can join the discussion forums. Our meetings are open; they're video streamed; anybody can speak at any time. You can ask questions online as well as at the physical meetings. Journalists can attend. It's a very different culture.

A top-down entity, only consisting of governments as the decision-makers, would represent a dramatic disruption to the successful partnership of the technical and engineering communities, business, academia, and governments which has been critical for the success of the Internet. It could well fracture, weaken, and politicize the technical-coordination functions. It would represent a very severe disturbance not only to ICANN but also the other bottom-up consensus bodies which play a key role in the diverse development and functioning of the Internet.

TR: Yet the international community is still demanding a greater say in the way ICANN operates. Was the creation of several "at-large community user groups" in December a response to those requests?
TWOMEY: Yes and no. First of all, ICANN from its beginning has had its focus on being international. I'm Australian, and the staff are based on three continents. Our board members are required to come from five regions around the world. Similarly, the supporting organizations are all required to have their members come from different parts of the world. So it is a very international organization in its structure.

The "at large" issue is really putting in this final leg of representation of the consumers' interests. We're trying to put in place a mosaic of international groups that actually represent all consumers. The committee has been working off a list of something like 350 different types of consumer organizations—people who've got an interest in the Internet—who they are approaching to be a part of this structure. We actually want to build in a structure that is very bottom-up representative of the consumers on the Internet.

TR: What is the biggest challenge for the Internet from ICANN's perspective?
TWOMEY: The Internet is becoming very local while at the same time being global. People want to communicate in their own languages—in Japanese, Chinese, Bahasa. What that means is that the Internet won't be as transparent to all users; people who are used to using [English] characters might have trouble trying to find a particular company that's got its domain name in Chinese characters. So we have to ensure that we maintain a single interoperable Internet, and we don't end up with a series of Internets. From an ICANN perspective, this is our most important challenge. We can do quite a lot of stuff around internationalized domain names, allowing people to have top-level domains [like .com or .net] in their own character sets. That's [ICANN's] core business. What other people are going to have to do is [design] how search engines are going to work, how people are going to find other players, how you are going to have translation systems across the Internet.

To take a western-European historical perspective, it's a little bit like going from Christendom to the nation-states in Europe. You had this Christendom, and everyone spoke either Greek or Latin. There was a common language, and it all worked. All of a sudden there were these nation-states where everybody spoke their own language. How do you speak together? It's the same sort of process. English has been the Latin of the Internet, but it's not going to be anymore.

Mark Frauenfelder is based in Los Angeles.

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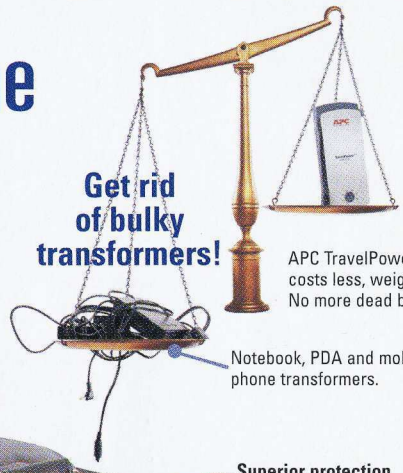

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Smarter Drugs

BY CORIE LOK

If you could watch what happens to a typical drug in your body, you'd probably see its ingredients spread quickly, even to places where they are not needed. The drug doesn't always arrive at the right place at the right time or stick around long enough to have its full benefit. So drug developers often combine medicines with other compounds to maximize benefits and minimize side effects. Indeed, researchers are always looking for ways to more precisely control the timing, targeting, and dosage of drugs.

A Rutgers University startup, Polymerix, has a novel approach that could boost the potency of some drugs and provide for their steadier release over time. Whereas other drug delivery methods employ polymers—long molecular chains with carbon backbones—that degrade slowly to help control drug release in the body, Polymerix forms similar chains out of the drug molecules themselves. The technology delivers drugs more efficiently and at higher concentrations than conventional polymer carriers, says Kathryn Uhrich, a Rutgers chemistry professor and Polymerix's scientific founder. The company's drug formulations can be used in injectable or implantable forms or even as pills. For now, however, Polymerix is developing anti-inflammatory drug coatings for medical devices.

Founded in 2000, Polymerix secured $8.4 million in second and third rounds of venture financing last October, including $4.5 million as part of a deal with a medical-device company to develop anti-inflammatory coatings for stents—metal meshes inserted into narrowing coronary arteries. The intention is that the coating will degrade, release its anti-inflammatory drug, and prevent a common complication of stenting: artery reclogging thought to be triggered by an inflammatory response to the stent's insertion. "We're the first to create an anti-inflammatory biodegradable coating for medical devices," says Karen Giroux, Polymerix's chair and CEO. Polymerix hopes to have the stents in human clinical trials next year.

POLYMERIX

HEADQUARTERS: Piscataway, NJ

UNIVERSITY: Rutgers

INVESTMENT RAISED: $16 million

LEAD INVESTORS: AMT Capital, Sherbrooke Capital

FOUNDERS: Kathryn Uhrich, Karen Giroux, Robert Butz

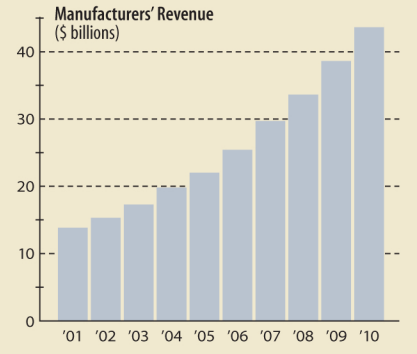
In general, polymers enable better control of drug release because it takes time for the body to break the chemical bonds between a polymer's molecular building blocks. As more bonds are cleaved, the polymer erodes, gradually releasing drugs contained inside and providing a more consistent level of medication over time. Polymerix's compounds degrade the same way. Water breaks the bonds between the drug molecules one by one, releasing them slowly and steadily.

A key advantage to eliminating the use of a polymer carrier is that a formulation can contain a higher percentage of active ingredient: while conventional polymer-based drug delivery systems are at most 30 percent drug, Polymerix's are 70 to 90 percent. For diseases such as cancer and arthritis that require a high dose of drug in a small, local area, this could mean more drug delivered with fewer shots and, ultimately, more effective treatment. With Polymerix's strategy, "there's much more control over how the drug is released," says Michael Pishko, a materials science and chemical engineering professor at Pennsylvania State University who is developing polymer-based drug delivery systems. For example, linking drug molecules into a long chain keeps them from being released too quickly in potentially dangerous quantities.

Polymerix's new products will face challenges, however. While most polymers used today in drug delivery are already approved by the U.S. Food and Drug Administration, each of Polymerix's compounds will likely have to be approved as if it were a new drug. And Polymerix will have to prove that linking drug molecules together won't affect their biological activity.

Even so, Giroux believes the technology could be applicable to many different types of medicinal compounds, including cancer drugs. If she's correct, it could play a critical role in making drug delivery a little bit smarter. TR

U.S. MARKET FOR DRUGS USING NEW DELIVERY TECHNOLOGIES



SOURCE: "ADVANCED DRUG DELIVERY TECHNOLOGIES APPLICATIONS AND MARKETS," KALORAMA INFORMATION, A DIVISION OF MARKETRESEARCH.COM (CHART)

PLAYERS IN ADVANCED DRUG DELIVERY

COMPANY	TECHNOLOGY
Alkermes (Cambridge, MA)	Microspheres of polyesters that encapsulate drugs, releasing them over days to months
Alza (Mountain View, CA)	Injectable polyester solution that releases drugs in the body over weeks to months
Angiotech Pharmaceuticals (Vancouver, British Columbia)	Drug coating for cardiovascular stents
SkyePharma (London, England)	Injectable microscopic particles made of lipids that encapsulate pain and cancer drugs for sustained release over days to weeks

RFID

Radio frequency identification technology is finally coming into its own. Wal-Mart, the nation's largest retailer, has asked suppliers to attach RFID tags to product shipment palettes by 2005 to automate tracking. EPCGlobal, an international organization helping to drive and implement the technology, is building a network in which every consumer item will have a tag and an electronic product code, or EPC. But drawbacks to RFID technology, including its high cost and concerns about consumer privacy, must be overcome before it finds widespread use. Here's how tracking with RFID tags is expected to work in the supply chain. **TEXT AND ART BY 5W INFOGRAPHIC**

WHAT IS RFID?

There are three components to an RFID system:

TAG

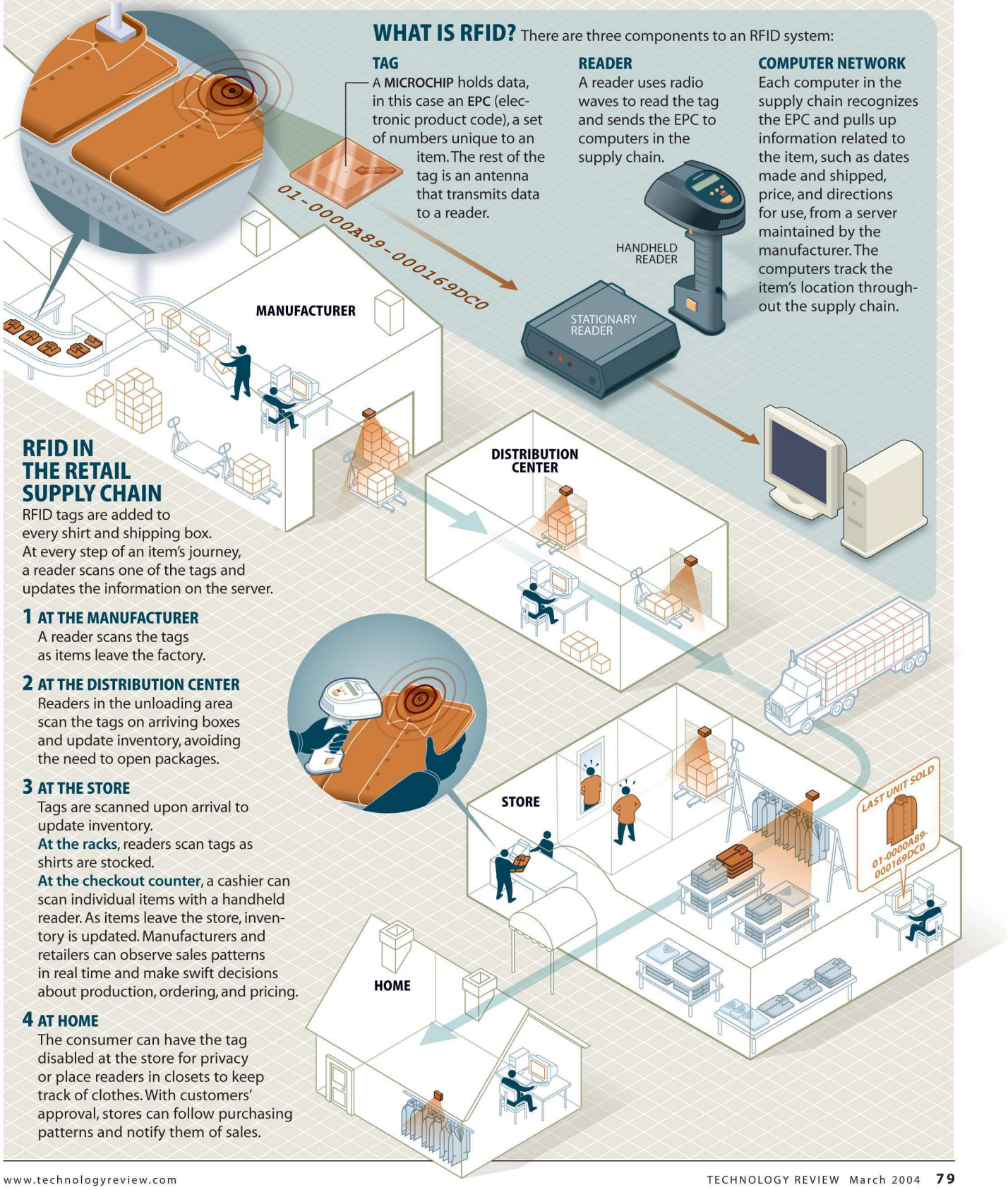
A **MICROCHIP** holds data, in this case an **EPC** (electronic product code), a set of numbers unique to an item. The rest of the tag is an antenna that transmits data to a reader.

READER

A reader uses radio waves to read the tag and sends the EPC to computers in the supply chain.

COMPUTER NETWORK

Each computer in the supply chain recognizes the EPC and pulls up information related to the item, such as dates made and shipped, price, and directions for use, from a server maintained by the manufacturer. The computers track the item's location throughout the supply chain.



RFID IN THE RETAIL SUPPLY CHAIN

RFID tags are added to every shirt and shipping box. At every step of an item's journey, a reader scans one of the tags and updates the information on the server.

1 AT THE MANUFACTURER

A reader scans the tags as items leave the factory.

2 AT THE DISTRIBUTION CENTER

Readers in the unloading area scan the tags on arriving boxes and update inventory, avoiding the need to open packages.

3 AT THE STORE

Tags are scanned upon arrival to update inventory.

At the racks, readers scan tags as shirts are stocked.

At the checkout counter, a cashier can scan individual items with a handheld reader. As items leave the store, inventory is updated. Manufacturers and retailers can observe sales patterns in real time and make swift decisions about production, ordering, and pricing.

4 AT HOME

The consumer can have the tag disabled at the store for privacy or place readers in closets to keep track of clothes. With customers' approval, stores can follow purchasing patterns and notify them of sales.

SOURCES: AUTO-ID CENTER, EPCGLOBAL, WAL-MART

Dial *N* for Net Phone

I FIRST HEARD ABOUT INTERNET TELEPHONY BACK in 1985, when MIT professor Steven Burns told me about an "Etherphone" that some researchers at Xerox had created to send voice over a computer network. The system worked by taking a person's voice, digitizing it, breaking that digital data into packets, and finally sending those packets over a high-speed network. At the other end, another Etherphone reversed the whole process. Neat technology, I thought, but far too computationally intensive and wasteful of resources to ever be practical.

How wrong I was. In the past 18 years, computers have gotten more than 1,000 times faster and networks nearly 100 times faster, but the human voice has remained basically unchanged. As a result, it's now dirt cheap to send reasonably high-quality voice over the Internet. And with programs like Microsoft NetMeeting, Apple's iChat, and Skype, it's relatively easy for anyone with a decent PC and sound card to set up a two-way voice or video conversation over the Net—provided that you don't mind making all of your phone calls in front of your computer, and that the only people you want to call are other people sitting in front of their computers.

But even this arrangement is obsolete. A new service called Vonage offers a completely different approach to Internet telephony. It still uses your high-speed Internet connection, but instead of a desktop computer, you make your phone calls using a special "telephone adaptor" that's about the size of a trade paperback. You plug this adaptor into your home network's hub or router, and into the wall for power. Then just plug a standard telephone into the adaptor and you're ready to go.

The Vonage adaptor is a tiny digital-telephone branch office in a box. It provides the dial tone when you pick up your phone and rings the bell when there is an incoming call. It digitizes your voice and sends it over the Internet to Vonage's servers, where calls are transferred to the same public telephone network that traditional telephones and cell phones use. Indeed, unlike NetMeeting, Skype, and the others, Vonage lets you make real telephone calls to other phone numbers. Vonage also provides you with your own phone number that anybody can call.

I once thought that Internet telephony was a neat technology but too computationally intensive to ever be practical. How wrong I was.

Another difference between it and the others is that Vonage costs real money—but not much. The basic plan offers 500 minutes of calling anywhere in the United States and Canada for $15 a month. That plan includes caller ID, voice mail, call forwarding, and other features that phone companies typically charge extra for. Unlimited local calling with 500 minutes of long distance is $25 a month. For $35 a month, you can have unlimited calling anywhere in the country. Plus, the adaptor has two phone jacks on its back, allowing you to add a second phone number for a fax machine or your kids for a small additional fee.

Vonage's servers are oblivious to geography. When you sign up, the company asks you in which area code you would like to list your phone number. I have a friend in France; his Vonage phone has a Maryland area code because that's where he used to live. If I call him from my cell phone, the conversation moves over the telephone network on its way from Massachusetts down to Maryland, then hops on the Internet for the trip across the Atlantic. The result: no international telephone charges! And he can call anywhere in the United States without paying a centime to France Telecom.

The Vonage adaptor is delightfully easy to use. I didn't bother reading the directions when mine came in the mail: I just plugged it into my network, connected it to a cheap telephone, picked up the receiver, and dialed. I heard a normal ring at the other end of the line, the person answered, and we started talking.

Alas, there are some problems with the Vonage system. It takes between five and ten seconds longer for local phone calls to connect over Vonage than over my landline. The caller ID only shows the caller's phone number, not his or her name. Sound quality is great over a high-speed connection, but with a 144-kilobit-per-second ISDN hookup it is often garbled—like a poor cell-phone connection. My biggest concern, though, is reliability: unless you have battery backup for your Internet connection, the Vonage phone won't work if the power goes out. You can mitigate this concern to some extent by having your Vonage phone number automatically forward to another, regular telephone number if your Internet connection fails.

Other companies are entering the consumer and small-business Internet telephony market, but with more than 100,000 customers, Vonage is the leading player. If you already have a high-speed Internet connection, this is an easy way to shave cash off your monthly phone bill.

Simson Garfinkel is an incurable gadgeteer, an entrepreneur, and the author of 12 books on information technology and its impact.

Get in the zone with the mattress topper that molds to your body's contours

The Memory Foam Ultra mattress topper is cut into a grid pattern combining six different zones for variable support and a better night's sleep.

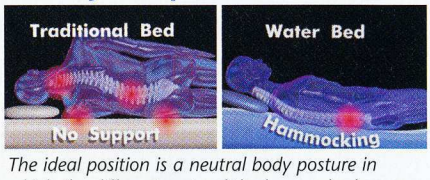
The 2-inch thick temperature-smart foam adjusts to your shape.

It's 3 a.m. You have exactly two hours until you have to get up for work, and you still can't seem to fall asleep. At this point, the phrase "tossing and turning" begins to take on a whole new meaning for people whose mattresses simply aren't giving proper support anymore. Your mattress may dictate your quality of sleep. Even if you merely suspect that your mattress may be outdated, that's when you need to take action. Some mattresses fail to support your spine properly, which can result in increased pressure on certain parts of your body. Other mattresses, sporting certain degrees of visco-elastic foam, can sometimes cost you well over $1000. Now, one of the world's leading manufacturers of foam products has developed an incredibly affordable mattress topper that can actually change the way you sleep. Introducing the future of a better night's sleep: The Memory Foam Ultra mattress topper.

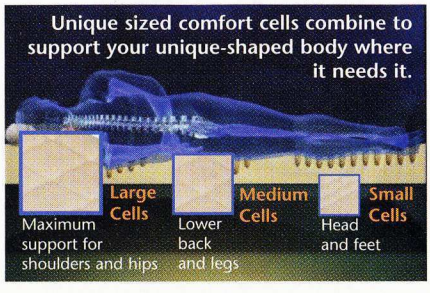
Sleep Better™...Wake up to a better morning. The Memory Foam Ultra mattress topper is designed to give you a better sleep surface. Not only does it support each region of your body, but it's also temperature sensitive. With its various-sized "comfort cells," the 2-inch thick Memory Foam Ultra mattress topper combines six zones to support specific body area weight, which promotes a better night's sleep. The largest cells support your lower back and midsection, while the medium-sized cells support the shoulders, lower back and legs. The smallest cells support your head and feet. Combined, these zones provide variable support from head to toe. By using visco-elastic foam, the Memory Foam Ultra mattress topper also molds to your body contours to help prevent tossing and turning during the night. When you lie down on this amazing material, the heat and pressure sensitive foam reacts to your body's weight and temperature, so that it molds to your exact body shape. This means that whether you sleep on your back, stomach or side, your weight is evenly distributed and your spine remains in a neutral position. Other surfaces support your body at the shoulders, hips and legs only. This causes your spine to sag in other areas, which can often result in discomfort, and even back pain. You'll wake up rested, relaxed and ready to take on the day. Anyone who suffers from insomnia and back pain due to mattress discomfort can benefit from this technology.

Superior sleep products designed to help you sleep better™ CARPENTER We bring comfort to your life®

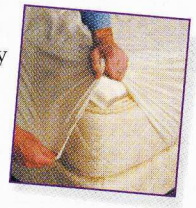
What could be wrong with your present bed?



The ideal position is a neutral body posture in which the different parts of the human body are supported individually and evenly. This is the secret behind Memory Foam Ultra, the mattress topper that turns any bed into the ideal sleep surface.



FREE heavyweight mattress pad included. Included with the Memory Foam Ultra mattress topper is a fitted mattress pad. It's heavyweight and quilted, and made of 200-count 100% cotton with a 14-inch deep stretchable skirt to fit a mattress up to 21 inches thick. The size of the mattress pad is determined by the size mattress topper you order.



Try it for yourself today! The Memory Foam Ultra mattress topper can change the way you sleep. Promote proper spine positioning, while enjoying relief from insomnia and back pain with this full-body support. It comes with a 5-year manufacturer's limited warranty and TechnoScout's exclusive in-home trial. If you are not completely satisfied, simply return it within **60 days** for the full purchase price.

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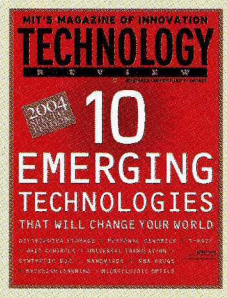

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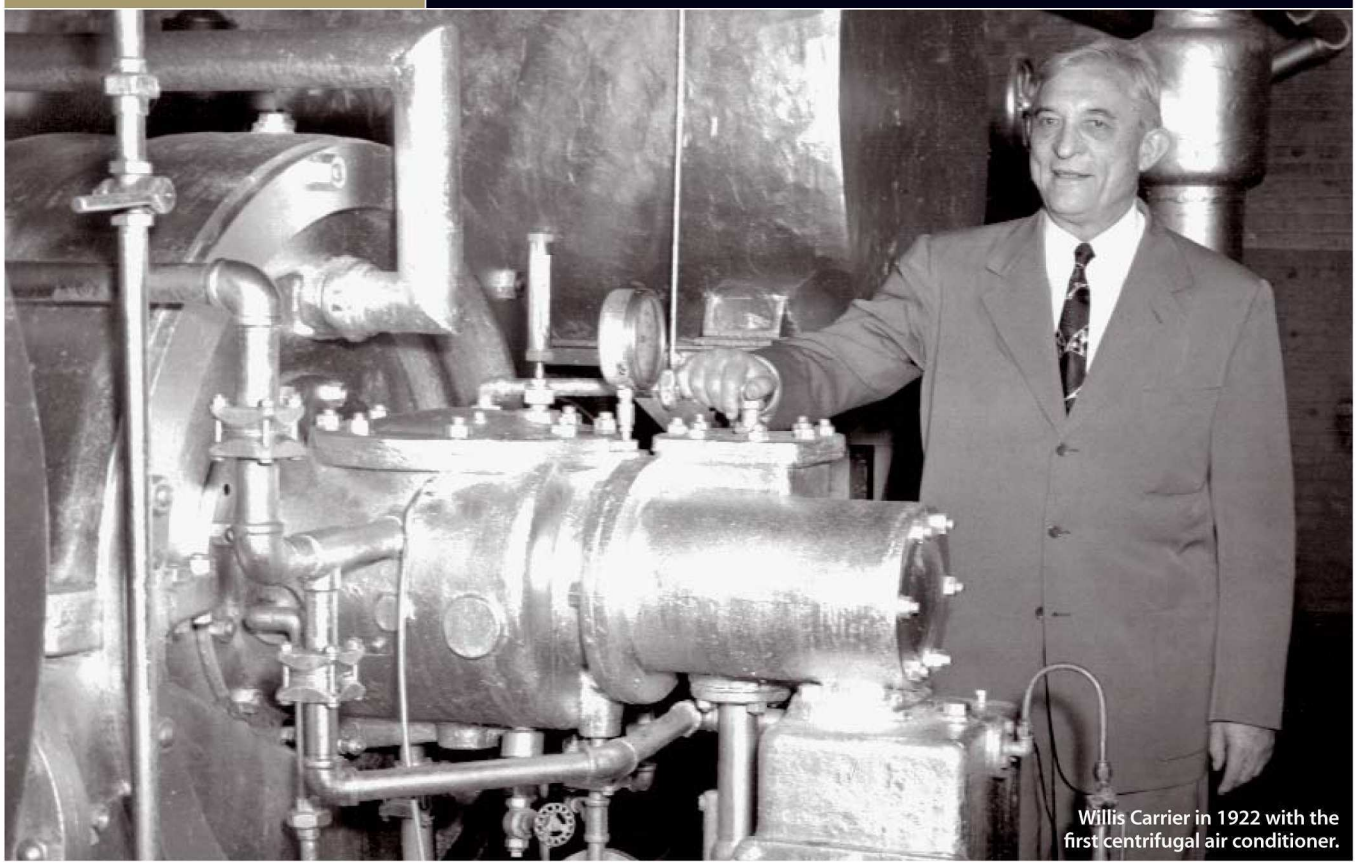

Willis Carrier in 1922 with the first centrifugal air conditioner.

The Birth of Cool

The history of modern air conditioning. **BY LISA SCANLON**

While standing on a foggy railroad platform in Pittsburgh in late 1902, Willis Carrier had a revelation that would lead to the invention of the modern air conditioner. Carrier's device evolved from candy-factory chiller to the heat- and humidity-busting personal cooling units now found in more than 80 percent of United States homes.

In July 1902, the 25-year-old engineer had finished designing the first modern air-conditioning system for a Brooklyn, NY, printing press that wanted to prevent its paper from warping. Unlike previous cooling systems, Carrier's device regulated humidity in addition to temperature. But Carrier wasn't satisfied with this first system; he felt that it needed more exact controls. On that cold, foggy platform a few months later, Carrier recognized that the lower the temperature, the less water the air could hold. He reasoned that he could raise or lower a room's humidity by using a device that passed air through a hot- or cold-water sprayer.

This idea grew into a series of formulas for regulating air temperature and humidity—the basis of important calculations that still serve the air-conditioning industry. Carrier's installations soon became a hit with candy factories, celluloid-film makers, and breweries. However, during World War I, Carrier's parent company decided to cut back on his research funding. Undeterred, Carrier and six coworkers created an independent company, Carrier Engineering.

In 1922, Carrier unveiled another major breakthrough: the centrifugal refrigeration machine. Carrier's new design pumped coolant through the machine much more efficiently, allowing for larger, more stable machines. This made air conditioning practical for places like department stores and movie theaters.

In 1928 Carrier created a residential "Weathermaker" that heated, cooled, humidified, cleaned, and circulated air in homes, but the Great Depression put off its commercialization. World War II further delayed the arrival of residential air conditioners, as Carrier Engineering regeared its production lines to the war effort. The company's systems were used to simulate freezing, high-altitude conditions for the testing of prototype planes, and Carrier chillers were taken from department stores and installed in war production plants.

Although Carrier died in 1950 before seeing his invention's sweeping residential success, his company remains one of the world's largest manufacturers of air-conditioning equipment for residential and commercial applications. TR

COURTESY OF CARRIER

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